INSTRUCTION MANUAL

MODEL 110 /110B

FUNCTION GENERATOR

and

MODEL 111 /111B

VOLTAGE CONTROLLED GENERATOR

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WAVETEK

8159 ENGINEER ROAD, SAN DIEGO, CALIFORNIA

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Model 110 and 110B Function Generator

Model 111, VGG Voltage Controlled Generator

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WARRANTY

WAVETEK warrants instruments manufactured by it to have met Wavetek's published specifications at the time of shipment of such instruments, and agrees to repair within one year of shipment, such instruments or their components (excluding batteries), which under normal use are found to be defective as a result of our manufacturing. Our obligation under this warranty is limited solely to repairing any such instrument which in our sole opinion proves to be defective when returned to our factory. Transportation to the factory is to be prepaid by purchaser. Instruments returned to the factory will be accepted only when prior authorization has been given by a representative of Wavetek.

This warranty does not apply to any of our products which have been repaired or altered by persons not authorized by us, or not in accordance with instructions furnished by us. If the instrument is defective as a result of misuse, improper repair, or abnormal conditions or operations, repairs will be billed at cost.

Wavetek assumes no responsibility for its product being used in a hazardous or dangerous manner either alone or in conjunction with other equipment. Wavetek assumes no liability for secondary charges or consequential damages, and in any event, Wavetek's liability for breach of warranty under any contract or otherwise, shall not exceed the purchase price of the specific instrument shipped and as to which a claim is made.

Any recommendations made by Wavetek for the use of its products are based upon tests believed to be reliable, but Wavetek makes no warranty of the results to be obtained. This warranty is in lieu of all other warranties, express or implied, and no representative or person is authorized to represent or assume for us any liability in connection with the sale of our products other than set forth herein.

SECTION I
GENERAL DESCRIPTION AND OPERATION

GENERAL

The WAVETEK Model 110 Function Generator and Model 111 Voltage Controlled Generator (VCG) are semi-precision sources of waveforms from servo to video frequencies. These units are extremely rugged, completely transistorized portable packages. They feature complete plug-in printed circuit board construction with interchangeable individually calibrated PC boards utilizing silicon semiconductors throughout. The extremely clean and stable waveform signal from 0.005 Hz to 1 MHz (Model 110) and 0.0015 Hz to 1 MHz (Model 111) make these generators highly versatile general purpose pieces of equipment for the laboratory or the field.

The Models 110 and 111 are identical in size and performance except that the Model 111 offers VCG and the additional ramp function. Both Models feature a main output with function selector switch and amplitude attenuator, and in addition, simultaneous 5v peak to peak 50 ohm outputs of sine, square and triangle waveforms. In addition, they offer a 1v 5 nsec rise and fall time square wave and -10v sync pulse. Frequency is controlled by an eight position range switch at 20:1 range thus providing good overlap.

All outputs may be shorted simultaneously and the generator will continue to oscillate internally with less than 0.5% change in frequency. Voltage may be applied back into the generator so long as this voltage does not exceed the maximum output voltage. Up to $\pm$ 50v may be applied to the VCG input without damage.

MODEL 111

The Model 111 features VCG voltage control of frequency by the internal frequency dial operating in parallel with the VCG input terminals. The generated frequency is the resultant sum of the VCG input voltage and the dial setting. Without an externally applied voltage, the dial governs and the generator operates like a Model 110. By adding a positive voltage to the input terminals, the frequency is increased; by adding a negative voltage to the input terminals, the frequency is decreased. The applied voltage may be either a DC programming voltage or an AC frequency modulating voltage. The modulation band width is 100 KHz (it is possible to have a higher modulation frequency than carrier frequency, with a resulting triangle wave that may look like a staircase).

The frequency dial is a continuously variable quality composition pot. An electronic frequency vernier is incorporated for extremely precise frequency adjustment. The vernier covers one minor dial division for one vernier rotation.

In addition to sine, square and triangle, the Model 111 also offers ramp functions. The base line of this ramp signal is 0v and the ramp duty cycle is 50%. The ramp on the binding post

is a positive ramp; the ramp on the BNC connector is a negative ramp.

MODELS 110 and 111; MODELS 110B and 111B

The Models 110 and 111 incorporate a power amplifier which offers a maximum of 32.5v peak to peak (+16.25v ramp) at the binding post output. An attenuator is included on the input of this output amplifier. The amplifier will supply 30v peak to peak (15v ramp) into a 600 ohm load at maximum output setting. Ten volts peak to peak (5v ramp) may be driven into a 50 ohm load with undistorted waveform by rotating the output attenuator counter-clockwise until clipping stops. Very low impedance loads can be driven without distortion by further rotation of the output attenuator.

NOTE

When a relatively small output signal is needed, it is recommended that the output be attenuated by an external pair of resistors to a level approximating that required and the internal attenuator be used as the amplitude vernier. Attenuating the output by 10:1, 100:1, or 1,000:1, etc. The use of a pair of external resistors will insure clean waveform quality and good resolution by the internal attenuator in low level applications.

The output amplifier inverts the signals appearing at the BNC connectors. Thus there will be a 180° phase shift between the sine, square or triangle output appearing on the binding posts and those on the BNC's. The ramp on the binding post will be simultaneous in time with the ramp on the BNC; however, it is a positive ramp while the BNC is a negative ramp. Both have a base line very near zero volts.

The Models 110B and 111B incorporate a internal battery charger in place of the power amplifier. These units will operate continuously for eight hours (110B) or six hours (111B) from the internal batteries. Both may be charged completely in 16 hours. The charger is designed so that charging occurs while the unit is in operation. A screwdriver adjustment enables the operator to set the desired charge rate. In maximum cw position, charge time from discharge to charge is 14 hours. Frequent operation with the instrument plugged into AC power with the charge rate set this high would result in damage to the batteries. Maximum ccw position of the rear control sets the charge rate to maintain the batteries at full charge without overcharge. The units are wired so that when plugged into AC power, but turned OFF, a trickle charge maintains the batteries at full charge setting.

The power amplifier used in the 110 and 111 is not utilized in the 110B and 111B and is thus bypassed. The signal appearing on the binding post is now a maximum 5v peak to peak (-2.5v ramp) at approximately 600 ohm output impedance. Because no inverting amplifier is used, output signals on the binding post are directly in phase with those on the BNC's

MODELS 110 and 110B CONTROLS AND TERMINALS

Controls and outputs for the Models 110 and 110B are identical except for output impedances and voltage levels at the binding posts. For the Model 110, these are 50 ohms and zero to 32.5v p-p (or, by removal of one jumper, an impedance of 600 ohms is obtained). Output impedance of the Model 110B is 600 ohms at voltage levels of zero to 5v p-p. No zero adjustment is provided for this output on the Model 110B, but internal controls permit setting the balance of each function independently.

POWER SWITCH. The power switch on the Model 110 connects the instrument to either 115 VAC or 230 VAC line power through a 3/4 ampere fuse mounted on the rear panel. (see drawing in Schematic section of handbook for 115 VAC and 230 VAC connections.)

For the Model 110B, when the power switch is OFF, the batteries are disconnected from the instrument but connected to the charger. The charger is set for a trickle-charge of approximately 3 ma if it is plugged into the power line. In the ON position, the batteries are connected to the instrument for normal operation. If the instrument is not connected to line power, the batteries are discharging; but, if connected, the charger supplies sufficient current to operate the instrument and charge the batteries. The amount of charge current is dependent upon the potentiometer available through the rear panel. In maximum clockwise rotation the charge current is approximately 50 ma. In maximum counter-clockwise rotation the charge current is approximately 15 ma. The 15 ma charge current is recommended for optimum battery life unless a greater charge rate is required by duty use cycle.

CAUTION

If the batteries are allowed to completely discharge, the instrument power supply cannot provide adequate power to simultaneously operate and charge. If this condition exists, the instrument should be allowed to recharge for at least one hour before it is used in the AC mode.

FREQUENCY RANGE SWITCH. An eight position switch which selects the appropriate timing resistor and capacitor for proper frequency range and selects appropriate compensating resistors for constant dial pot loading, and balanced integrator source resistances.

FREQUENCY DIAL. A continuously variable high quality composition pot which allows precise frequency adjustment. The generated frequency is the product of the dial setting and the frequency range switch multiplier; for instance, if the dial setting is 3-1/2, and FREQ Hz dial is at X100, the frequency generated is 350 Hz.

SELECTOR SWITCH, OUTPUT ATTENUATOR, AND DC ZERO CONTROL (rear-mounted screwdriver adjustment). Output impedance is 50 ohms, but output is current limited to drive approximately $\pm$ 100 ma into a short circuit. Output at maximum clockwise attenuator position is 32.5v p-p open circuit, and 30v p-p into 600 ohm load. For load impedance less than 600 ohm, the attenuator must be rotated counter-clockwise or clipping will result.

Maximum undistorted output into a 50 ohm load is 10v p-p.

The output attenuator covers a 50 db range. For output voltages less than 20 db below maximum output, it is recommended that an external attenuator using a pair of resistors be used and the internal attenuator be used for fine control. For a 10:1 attenuator, use a 470 ohm resistor in series in a 56 ohm shunt with the load. For a 100:1 attenuator, use 1K in series and 10 ohms in shunt, or 4.7K in series and 51 ohms in shunt (these values are indicative and not critical). The attenuator is located in the input/output amplifier. As a result, the zero adjust will be most critical at minimum setting. The rear-mounted dc adjustment control should be adjusted with the attenuator in maximum counter-clockwise position.

NOTE

Zero adjust control is a high resolution Zero Adjust Potentiometer not a dc offset control

Switch selected sine, square, and triangle waves will have equal p-p amplitude for all attenuator settings.

THE 5V TRIANGLE, 5V SINE AND 5V SQUARE OUTPUTS. These outputs are accurate 5v, 50 ohm sources balanced about ground. They will drive 2.5v p-p into a 50 ohm load, and supply ± 50 ma peak into a short circuit.

THE 5 NSEC SQUARE OUTPUT. The 5 nsec square output is approximately 1v p-p open circuit, 0.5v p-p into a 50 ohm load with better than 5 nsec rise and fall time. Always use a 50 ohm cable and a 50 ohm termination when using this output.

SYNC OUTPUT. At least -10v sync signal of Typical 1.5 us pulse width. The pulse occurs once per cycle coincident with negative transition of 5v square wave, and a negative peak of sine and triangle waves.

NOTE

Due to its very narrow pulse width, the sync pulse is difficult to observe at low frequencies. However, it will trigger wide band scopes such as the Tektronix Model 453 at all frequencies.

MODELS 111 AND 111B CONTROLS AND TERMINALS

POWER/DIAL MULTIPLIER SWITCH. This switch incorporates two ON positions, X .3 and X1. This switch, in conjunction with the frequency range switch and the frequency dial determines the generated frequency. For example, the dial is set at 3 1/2, the frequency range switch setting is X100, and the dial multiplier switch at X1, the frequency generated is 350 Hz. With the dial multiplier switch at X.3, the frequency is 105 Hz.

In the Model 111B, when the switch is in the OFF position, the batteries are disconnected from the instrument but connected to the charger. The charger is set for a trickle-charge of approximately 3 ma when the instrument is connected to line power. In the ON position, the batteries are connected to the instrument for normal operation. If the instrument is not connected to the line power, the batteries are discharging; if connected, the charger supplies sufficient current to operate the instrument and charge the batteries. The amount of charge current available is variable through the potentiometer at the rear panel. In maximum counter clockwise rotation the charge current is approximately 15 ma. The 15 ma charge current is recommended for optimum battery life unless the maximum charge rate is required.

CAUTION

If the batteries are allowed to completely discharge, the instrument power supply cannot provide adequate power to simultaneously operate and charge. If this condition exists, the instrument should be allowed to recharge for at least one hour before it is used in the AC mode.

FREQUENCY RANGE SWITCH. The frequency range switch selects the appropriate timing resistor and capacitor for proper frequency range.

FREQUENCY DIAL AND FREQUENCY VERNIER. The frequency dial is a high quality composition pot providing continuous frequency control. In addition, an electronic vernier control is provided for precise frequency setting. Complete rotation of the vernier changes the frequency one minor dial division for all settings of the dial. The frequency vernier should be in extreme clockwise position (cal) for maximum dial accuracy.

THE VCG INPUT. The VCG input permits remote control of dial frequency and frequency modulation. The calibration factor is 0.5v per major dial division. A positive voltage causes an increase in frequency and a negative voltage causes a decrease. The setting of the frequency dial (and the frequency vernier) determines base frequency. The VCG input impedance is 10K ohms. Up to ± 50v can be applied to the VCG input without damage.

THE 5V TRIANGLE, 5V SINE AND 5V SQUARE OUTPUTS. These outputs are accurate 5v, 50 ohm sources that are balanced about ground. They will drive 2.5v p-p into a 50 ohm load, and supply ± 50 ma peak into a short circuit. The ramp output is 2.5v. Fixed ramp output is identical with fixed sine, square, and triangle output except that the base line is at zero volts ± 25 mv (5 mv typ). Open circuit voltage is a 2.5v negative going ramp. Ramp duty cycle is 50%. Negative ramp coincides in time with the negative going portion of the triangle wave and the positive half of the square wave. The ramp signal passing through the output amplifier is amplified and inverted so that the resultant ramp appearing at the binding posts runs from zero to a positive voltage.

MODEL 111B MAIN OUTPUT

Because no inverting amplifier is utilized, output waveforms in the switch-selected output

are in phase with fixed outputs. Maximum output is 5v p-p with 600 ohms output impedance and -2.5v ramp.

SECTION II
SPECIFICATIONS AND TEST PROCEDURES

This section contains specifications for the Wavetek instruments discussed in this handbook, and procedures for testing their accuracy. Table II-1 provides specifications for the Models 110 and 110B Function Generators, and Table II-2 is specifications for the Model 111 Voltage Controlled Generator.

VERSATILITY

Waveforms

Sine ∿ , square ⊓ , triangle △ and sync pulse.

Dynamic Frequency

0.005 Hz to 1 MHz (3.3 min. to 1 usec). NOTE: Dial is a high quality composition pot, allowing true continuously variable frequency control.

Ranges

X.01 = 0.005 Hz to 0.1 Hz.

X0.1 = 0.05 Hz to 1 Hz.

X1.0 = 0.5 Hz to 10 Hz.

X10 = 5 Hz to 100 Hz.

X100 = 50 Hz to 1 KHz.

X1K = 500 Hz to 10 Khz.

X10K = 5 KHz to 100 KHz.

X100K = 50 KHz to 1 MHz.

Six Simultaneous Outputs:

1) ∿ , ⊓ or △ selectable.
0 to 32.5v p-p at 50Ω output impedance. (600Ω output impedance available by removing one jumper wire.)

0 to 30v p p into 600Ω load. 0 to 10v p-p into 50Ω load.

Table II-1 Model 110 and 110B Specifications (Sheet 1 of 4)

Short circuit output current ± 100 ma.

Model 110B: 0 to 5v p-p at 600 Ω output impedance.

2) 50Ω ⊓⊔ 1v p-p, 5 nsec. rise time.

3) 50Ω ⊓⊔ 5v p-p, 15 nsec. rise time.

4) 50Ω ∿ 5v p-p.

5) 50Ω ∿ 5v p-p.

6) Sync pulse: At lease -10v into open circuit; less than 5 μsec. duration.

NOTE: All outputs may be shorted without damage to instrument.

HORIZONTAL PRECISION

Dial Accuracy

± 1% of full scale 0.005 Hz to 100 KHz.

± 2% of full scale 100 KHz to 1 MHz.

Frequency Stability

Short term: Drift less than ± 0.05% of setting for 10 minutes.

Long term: Drift less than ± 0.25% of setting for 24 hours.

No critical components requiring internal oven.

Jitter

± 0.025% cycle-to-cycle stability.

VERTICAL PRECISION

Frequency Response

Amplitude change with frequency less than 0.1 db 0.005 Hz to 100 KHz and 0.5 db to 100 KHz to 1 MHz.

Peak-to-Peak Voltage Accuracy

± 1% for 5v outputs.

± 1% for 32.5v output at maximum gain.

± 10% for 1v output.

Table II-1 Model 110 and 110B Specifications (Sheet 2 of 4)

Amplitude Stability

Short term: ± 0.05% of maximum p-p values for 10 minutes.

Long term: ± 0.25% of maximum p-p values for 24 hours.

Symmetry

All waveforms are symmetrical about ground within ± 1% of maximum p-p amplitude (external zero adjust rear-panel control provided for output #1).

DC Offset Stability

Short term: ± 0.05% of maximum p-p amplitude for 10 minutes.

Long term: ± 0.25% of maximum p-p amplitude for 24 hours.

PURITY

Sine Wave Distortion

Less than:

0.5% 0.005 Hz to 10 KHz.

1.0% 10 KHz to 100 KHz.

2.0% 100 KHz to 1 MHz.

Triangle Linearity

Greater than:

99% 0.005 Hz to 100 KHz.

95% 100 KHz to 1 MHz.

Square Wave Rise and Fall Time

1v output less than 5 nsec.

5v output less than 15 nsec.

32.5v output less than 100 nsec.

Total Aberrations

Less than 5% (overshoot, preshoot, etc.)

Tilt

Less than 0.5%.

Table II-1 Model 110 and 110B Specifications (Sheet 3 of 4)

Time Symmetry

All waveforms:

99.5%	0.005 Hz to 100 KHz.
99%	100 KHz to 1 MHz.

ENVIRONMENTAL

Temperature

All specifications listed, except stability, are for 25° C ± 5° C.

For operation from 0° C to 55° C, derate all specifications by a factor of 2.

Shock and Vibration

WAVETEK portables are designed to withstand shock and vibration far in excess of ordinary laboratory instrument. Similar models installed in trucks, ships and airplanes have been subjected to all kinds of rough treatment and continued to function according to specifications.

MECHANICAL

Dimensions

7-3/4" wide, 5-1/4" high, 7-1/2" deep.

Weight

7 lb. net, 10 lb. shipping.

Color

Clear anodized aluminum.

Controls

On-off power switch, frequency range switch, frequency dial, function selector switch, amplitude attenuator, dc zero adjustment (rear). All-silicon semiconductors, modular plug-in construction.

Power

Model 110: 105v to 125v or 200v to 250v, 50 Hz to 400 Hz. Less than 10 watts.

Model 110B: dc rechargeable ni-cad batteries provided with built-in charger. Eight hours of operation on batteries for every 16 hours of charge; simultaneous operation and charge.

105v to 125v or 200v to 250v, 50 Hz to 400 Hz. Less than 10 watts.

Table II-1 Model 110 and 110B Specifications (Sheet 4 of 4)

VERSATILITY

Waveforms

Sine , square , triangle , ramp
and sync pulse.

Dynamic Frequency

0.0015 Hz to 1 MHz (10 min. to 1 μsec).

Ranges

X.01 = 0.005 Hz to 0.1 Hz.

X0.1 = 0.05 Hz to 1 Hz.

X1.0 = 0.5 Hz to 10 Hz.

X10 = 5 Hz to 100 Hz.

X100 = 50 Hz to 1 KHz.

X1K = 500 Hz to 10 KHz.

X10K = 5 KHz to 100 KHz.

X100K = 50 KHz to 1 MHz.

X.003 = 0.0015 Hz to 0.03 Hz.

X.03 = 0.015 Hz to 0.3 Hz.

X.3 = 0.15 Hz to 3 Hz.

X3 = 1.5 Hz to 30 Hz.

X30 = 15 Hz to 300 Hz.

X300 = 150 Hz to 3 KHz.

X3K = 1.5 KHz to 30 KHz.

X30K = 15 KHz to 300 KHz.

Seven Simultaneous Outputs:

1) , , or selectable.

0 to 32.5v p-p (0 to + 16.25v ramp) at 50Ω output impedance. (600 Ω output impedance available by removing one jumper wire.)

0 to 30v p-p (15v ramp) into 600Ω load.

0 to 10v p-p (5v ramp) into 50Ω load.

Table II-2 Model 111 Specifications (Sheet 1 of 5)

Short circuit output current ± 100 ma.

Model 111B: 0 to 5v p-p at 600Ω output impedance.

2) 50Ω ⊓⊔ 1v p-p, 5 nsec. rise time.

3) 50Ω ⊓⊔ 5v p-p, 15 nsec. rise time.

4) 50Ω ∿ 5v p-p.

5) 50Ω ∿ 5v p-p.

6) 50Ω ⋀ 0v to -2.5v ramp; 50% duty cycle.

7) Sync pulse: At lease -10v into open circuit; less than 5 μsec. duration.

NOTE: All outputs may be shorted without damage to instrument.

VCG - Voltage-Controlled Generator

Over 20:1 frequency ratio (selectable in ranges of 3:1 allowing excellent range overlap). 4.75v input for 20:1 frequency ratio (0.5v per major dial division.) Input impedance 10K .

HORIZONTAL PRECISION

Dial Accuracy

± 1% of full scale 0.0015 Hz to 100 KHz.

± 2% of full scale 100 KHz to 1 MHz.

NOTE: Dial is a high-quality composition pot, allowing true continuously variable frequency control.

Electronic Frequency Vernier

One turn for one minor dial division.

VCG Linearity

± 0.1% frequency vs. input voltage (frequency error 0.1% of total deviation - best straight line method). 0.0015 Hz to 100 KHz generated frequency. From 10% of maximum dial frequency.

VCG Bandwidth

100 KHz

Frequency Stability

Short term: Drift less than ± 0.05% of setting for 10 minutes.

Long term: Drift less than ± 0.25% of setting for 24 hours.

No critical components requiring internal oven.

Table II-2 Model 111 Specifications (Sheet 2 of 5)

Jitter

± 0.025% cycle to cycle stability.

VERTICAL PRECISION

Frequency Response

Amplitude change with frequency less than 0.1 db 0.0015 Hz to 100 KHz and 0.5 db 100 KHz to 1 MHz.

Peak-to-Peak Voltage Accuracy

± 1% for 5v and 2.5v outputs.

± 1% for 32.5v output at maximum gain.

± 10% for 1v output.

Amplitude Stability

Short term: ± 0.05% of maximum p-p values for 10 minutes.

Long term: ± 0.25% of maximum p-p values for 24 hours.

Symmetry

All waveforms, except ramp, are symmetrical about ground within ± 1% of maximum p-p amplitude (external zero adjust rear-panel control provided for output #1).

DC Offset Stability

Short term: ± 0.05% of maximum p-p amplitude for 10 minutes.

Long term: ± 0.25% of maximum p-p amplitude for 24 hours.

PURITY

Sine Wave Distortion

Less than:

0.5% 0.0015 Hz to 10 KHz.

1.0% 10 KHz to 100 KHz.

2.0% 100 KHz to 1 MHz.

Triangle and Ramp Linearity

Greater than:

Table II-2 Model 111 Specifications (Sheet 3 of 5)

99% 0.0015 Hz to 100 KHz

95% 100 KHz to 1 MHz

Ramp Fall Time

Less than 200 nsec.

Square Wave Rise and Fall Time

1v output less than 5 nsec.

5v output less than 15 nsec.

2.5v output less than 100 nsec.

Total Aberrations

Less than 5% (overshoot, preshoot, etc.)

Tilt

Less than 0.5%.

Time Symmetry

All waveforms:

99.5% 0.0015 Hz to 100 KHz.

99% 100 KHz to 1MHz.

ENVIRONMENTAL

Temperature

All specifications listed, except stability, are for 25° C ± 5° C.

For operation from 0° C to 55° C, derate all specifications by a factor of 2.

Shock and Vibration

WAVETEK portables are designed to withstand shock and vibration far in excess of ordinary laborator instruments. Similar models installed in trucks, ships and airplanes have been subjected to all kinds of rough treatment and continued to function according to specifications.

MECHANICAL

Dimensions

7 3/4" wide, 5-1/4" high, 7 1/2" deep.

Weight

7 lb. net, 10 lb. shipping

Table II-2 Model 111 Specifications (Sheet 4 of 5)

Color

Clear Anodized aluminum.

Controls

Off X. 3 X1 power/dial multiplier switch, frequency range switch, frequency dial, frequency vernier, function selector switch, amplitude attenuator, dc zero adjustment (rear).

All-silicon semiconductors, modular plug in construction.

Power

Model 111: 105v to 125v or 200v to 250v, 50 Hz to 400 Hz. Less than 10 watts

Model 111B: dc rechargeable ni-cad batteries provided with built-in charger. Six hours of operation on batteries for every 16 hours of charge; simultaneous operation and charge. 105v to 125v or 200v to 250v, 50 Hz to 400 Hz. Less than 10 watts.

Table II-2 Model 111 Specifications (Sheet 5 of 5)

TEST PROCEDURES

GENERAL INFORMATION

Specifications apply only when the dial setting is between 0.5 and 10. Instruments should be within specifications within 15 minutes warm-up time. All specifications are for 25° C ± 5° C and 105 to 125 volts AC, 50 Hz to 400 Hz. All measurements must be made as described herein. Frequency stability specifications refer to constant termperature, line voltage, panel setting, and loads; testing must be made after one hour warm-up at defined conditions.

TESTING INFORMATION

All frequency measurements should be made with the function selector switch on sine ∿, output attenuator set in the maximum counter-clockwise most position, all outputs unconnected (and VCG input, Model 111) except the 5 nsec. square wave output which should be connected to a counter through a 50Ω cable using 50Ω termination at the counter. The frequency vernier (Model 111) should be at maximum clockwise position (cal). The generated frequency should be within specifications for all combinations of the range switch and frequency dial.

Time symmetry measurements should be made using this setup and by measuring the positive and negative half cycles of the square wave. The two half cycle measurements should differ by no more than 1% of the total one cycle measurement.

Cycle-to-cycle jitter measurements should be made with this same setup. An oscilloscope with a delaying sweep or frequency counter may be used for cycle-to-cycle time jitter measurement.

VCG linearity should be made by again using the same setup as above, with the addition of a low impedance (50Ω maximum) source connected to the VCG input.

VCG input voltage should be measured with a high accuracy voltmeter such as DVM or a differential voltmeter.

OTHER KINDS OF TESTS

All voltage measurements should be made with an accurate wide band peak measuring device. It is strongly suggested that a Tektronix type W, or type Z plug-in with an appropriate oscilloscope be used for making these voltage measurements. The measuring device should have at least 50KΩ input impedance and sufficient band width so that waveform peaks are accurately measurable. The measurements should be made individually with no loads connected to the instrument.

When making very accurate peak measurements, minor aberrations will be noted on the waveform due to the switching of the square wave. The peak value is that voltage that associates immediately prior to these minor aberrations. Accurate peak waveform measurements should be made at 1 KHz with the dial set at 10. Accurate high frequency measurements are difficult to make and require considerable care in lead connection, current, and cable termination.

Lack of symmetry is defined as the difference in the plus and minus peak voltages. For example: a 5v signal with 1% dis-symmetry could read +2.525v and -2.475v.

All fixed outputs should be measured individually with a function selector switch on sine ∿, and the amplitude attenuator in maximum counter-clockwise position. The switch selectable output should be measured with the attenuator in maximum clockwise position and the appropriate function selected. Nothing should be connected to the binding posts when making this measurement.

When measuring the selectable output amplitude of the 110B and 111B, the measuring device should have at least 500K input impedance. Sine distortion, triangle and ramp linearity, rise and fall time, total aberrations and tilt specifications should be made independently connecting only one output to the appropriate measuring device at a time.

BNC outputs (except sync) should be connected to the measuring device with a 50Ω cable properly terminated for making all high frequency measurements.

NOTE

Sine waveform distortion will be slightly less from 300 KHz to 1 MHz if the cable is not terminated.

Sync output and selectable output should be evaluated using maximum attenuator setting commensurate with the load.

GENERAL NOTE

The test procedures very specifically define individually making measurements without simultaneous load of the various connectors. Simultaneous loading of all outputs will have only a minor effect on the frequency amplitude and purity performance.

SECTION III
THEORY OF OPERATION

MODEL 110. Figure III-1 is a block diagram of the Model 110 Function Generator. An understanding of the Model 111 is best accomplished by first studying the Model 110.

A square wave is generated into an integrator composed of a wide band differential dc amplifier and integrating resistor R with integrating capacitor C. The output of the integrator is fed into the hysteresis and output switch. The hysteresis and output switch function like a Schmitt trigger with the limit points set wide apart. As a result they fire when the triangle wave reaches +2.5v and -2.5v. The firing of the hysteresis and the output switches reverses the square wave fed into the integrator and the triangle wave reverses direction. The result is simultaneous generation of a square wave and triangle wave of the same frequency with the positive half cycle of the square wave coincident with the negative going portion of the triangle wave.

The frequency of oscillation is determined by the R and C selected by the frequency range switch and by the amplitude of the square wave fed into the integrating resistor R. the $\pm$ 5v square wave is fed to the frequency dial potentiometer. Setting the pot at the top of the dial results in maximum voltage and thus maximum integrating current is generated resulting in maximum frequency. Frequency is directly proportional to the square wave amplitude appearing on the arm of the frequency dial potentiometer.

The sine wave is produced by shaping the triangle wave. The triangle wave is fed into a shaping network composed of resistors and diodes with transistor emitter follower biasing circuitry. As the triangle wave voltage passes through zero, loading of the triangle wave is minimal and thus slope is maximum. As the triangle wave voltage increases successively, diodes with current limiting resistors conduct causing the slope of the output to be less. The resultant waveform resembles a sine wave but is pointed at the top. The diodes are biased by transistor emitter followers whose base emitter junctions are opposite in polarity from the diodes. This provides a first order compensation for drifts due to temperature variations.

The increase in diode current at the peak of the triangle wave causes a pointed voltage pattern on the collectors of the emitter followers. This pointed waveform is combined out of phase with the somewhat pointed sine wave. The resultant waveform is an almost pure sine wave. The circuitry is completely symmetrical about ground using PNP transistors on one side and NPN transistors on the other. The sine wave produced by shaping is considerably less in amplitude than the triangle wave input and is thus amplified to be equal to the triangle wave.

The triangle wave output of the integrator, the sine wave output, and the square wave coupled through an associated amplifier are fed to the function selector switch and also to the simultaneous BNC outputs. The switch is coupled to the attenuator which in turn

drives the output power amplifier. In the 110B and 111B this power amplifier is replaced by a 560Ω resistor.

The entire instrument except the power amplifier runs off a current regulated ±6v and -6v. The power amplifier runs off of an unregulated ± 25v.

Real fancy curves

MODEL 111. The figure III-2 is a block diagram of the Model 111, Voltage-Controlled Generator. In the Model 111 unique circuitry is provided whereby the amplitude of the square wave fed to the integrator is controlled by an analog voltage. The integrating resistor R is connected to a PNP and NPN transistor switch which is connected in an inverted configuration. The bases of these transistor switches are driven from the output square wave. Negative square wave causes conduction of the PNP transistor, and positive square wave causes conduction of the NPN. These transistors connected in inverted configuration when in the conduction mode, have in the vicinity of 10 mv drop between their emitter and collector.

The VCG input and the frequency dial both drive an operational amplifier whose output is proportional to, but inverted from, the sum of the input voltages. The first operational amplifier drives the second operational amplifier which is designed for unity gain, but inversion about ground. As a result, a positive voltage appearing on the input causes a negative voltage at the output of the first amplifier and a positive voltage at the output of the second amplifier. A negative square wave thus causes integrating resistor R to be shorted to the negative voltage output of the first amplifier. A positive square voltage causes resistor R to be shorted to the positive voltage output of the second amplifier.

The circuit would be complete and work accurately except for the small drop across the switching transistors. This drop is compensated for by inserting a matching transistor in the feedback loop of the operational amplifiers. The base drive to the compensating transistor is designed to equal the base drive to the switching transistors. The switching transistors and the operational amplifiers must have good high frequency characteristics since square waves up to 1 MHz must be controlled. As a result, the basic circuitry is also capable of a wide band frequency modulation.

The ramp is formed by off-setting the triangle wave so that the positive peaks are at zero dc. This resultant waveform is shorted to ground by transistor switches during the positive going half cycle. A two-stage clipping circuit is used in order to provide a very flat base line near zero volts. The excellent linearity of the triangle wave is preserved. The high quality ramp signal is fed through an associated amplifier to the BNC connector and the function selector switch.

CIRCUIT DESCRIPTION

Refer to Model 110 and 111 Main Board schematic diagrams.

INTEGRATOR, MAIN BOARD

Q1 through Q10 and their associated circuitry make up the wide band d-c integrator amplifier. The "Freq Hz" switch on the front panel selects the appropriate integrating resistors and capacitors for frequency ranging.

Q1 and Q2 are a Darlington input pair for the minus input; Q14 and Q15 are a Darlington pair in the plus input. Transistors Q1 through Q4 are low current, high gain, wide band transistors which allow the inputs to operate with less than 40 nano amps of source current. The collectors of Q2 and Q3 work into a complex load made up of R1, R3, R4, C3, and the input impedance of Q5 and Q6. Q5 and Q6 form a differential amplifier stage driving the differential stage made up of Q7 and Q8. The output is taken off single ended at the collector of Q7 through the push-pull emitter follower, Q9 and Q10. CR1 and CR2 provide the bias voltage for Q9 and Q10 to prevent crossover distortion. R8 allows the d-c levels in the two sides of the amplifier to be balanced throughout. The triangle output is connected to pin 1. It is also fed through R22 to the sine converter and to the Hysteresis switch made up of Q25 through Q30.

HYSTERESIS AND OUTPUT SWITCH, MAIN BOARD

The transistors in the Hysteresis switch are connected to form a bi-stable switch. Either the Q25, Q26 side or the Q28, Q30 side can be on but not both at the same time. When the positive going triangle reaches the firing level set by R77, the Q26 side turns on and the Q28 side turns off. The triangle starts its negative slope and when it reaches the firing level set by R78, the Q28 side turns on and the Q26 side turns off. The Hysteresis switch is d-c coupled to the bi-stable output switch made up of Q31 through Q34. The square wave available from this output switch has a risetime of less than 5 nano seconds. The square wave is coupled to pin 10.

The 10 volt peak to peak square wave is differentiated, amplified and clipped by Q35, R96, C25, CR15, R101, C27, and R110 to provide a -10 volt sync spike which has a duration of less than 5 μsec. The sync pulse is coupled to pin 13. The square wave is also coupled to a push-pull super emitter follower made up of Q36 through Q39. R104 allows the output amplitude to be adjusted, R99 adjusts the waveform so that it is symmetrical about ground. Diodes CR16 through CR19 provide temperature compensation. The output of the super emitter follower is a 5 volt peak to peak square wave with a risetime less than 15 nano seconds, coupled to pin 11.

SINE CONVERTER AND AMPLIFIER, MAIN BOARD

Transistors Q11 through Q18 are emitter followers in the sine converter that bias and temperature compensate the clipping diodes, CR3 through CR10. Diodes CR3,

CR5, CR7, and CR9 clip the positive portion of the triangle at points set by the pots in the base of their associated emitter follower transistors. Diodes CR4, CR7, CR8, and CR10 clip the negative portion of the triangle. The diodes do not, however, clip the most positive and negative peaks of the triangle. Therefore, the input to the sine amplifier is a sine wave with small peaks at the top and bottom. The sine wave is fed to the plus input of the sine amplifier through R64. The sine amplifier is a d-c wide band operational amplifier connected in a potentiometric configuration. R69 is the feedback resistor. The peaks on the sine wave are also seen at the collectors of the emitter followers in the sine converter. These peaks are coupled through R54 and R56 to the minus input of the sine amplifier and peak cancellation occurs in the amplifier giving a clean sine wave at the output. The sine wave is coupled to pin 9. R60 adjusts the sine wave symmetry about ground and R64 adjusts the sine wave amplitude.

POWER SUPPLY AND OUTPUT AMPLIFIER BOARD

A-c voltage is coupled from the transformer to pins 14 and 15 to drive the bridge rectifier made up of diodes CR1 through CR4. Filtering is provided by C1 and C2. Q1 is a transistor connected and operated as a zener diode providing a reference voltage for the +6 volt supply. Q2 and Q3 make up a comparator type differential amplifier. Q2 and Q3 drive Q6 and Q7 which in turn drive the +6 volt pass transistor Q10. R24 allows the base of Q3 to be adjusted slightly negative with respect to ground. Q1 has a zener voltage of approximately 6.3 volts setting the base of Q2 slightly negative. R24 is adjusted to give an output of +6.00 volts. If the +6.00 volts tries to increase due to a change in line voltage or load current, the collector of Q1 becomes more positive. The base of Q2 becomes less negative (moves in a positive direction with respect to ground) and Q2 draws more current. The collector of Q2 moves less positive and this change is coupled through Q6 and Q7 to the base of Q10. This increases the resistance of Q10, returning the supply to +6.00 volts.

Q4 and Q5 form a comparator type differential amplifier in the -6.00 volt regulator. The base of Q4 is returned to ground through R6. The divider of R26 and R27 between the + and - 6 volt supplies sets the base of Q5 at ground. R9 allows a small adjustment of the currents in Q4 and Q5 to set the output and -6.00 volts. An increase in the -6 volts due to line voltage variation or load current variation, results in the base of Q5 moving negative. The collector of Q5 moves less negative (in a positive direction). This change is coupled to the bases of Q11 and Q12. Q11 and Q12 form a Darlington connected pass transistor pair for added gain. The positive going change, increases the resistance of Q11 and Q12, returning the output to -6.00 volts.

OUTPUT AMPLIFIER

Q13 through Q18 form an operational output amplifier with a gain of approximately -6 set by feedback resistor R37 and the input resistor made up of R31 and R32. Transistors Q13 and Q14 are a differential input stage driving a second differential stage of Q15 and Q16. The output is taken off single ended at the collector of Q16 and coupled to the push-pull emitter follower, Q17 and Q18. Diodes CR5 and CR6

provide bias for the push-pull emitter follower to prevent crossover distortion. The output is coupled through R50 and R51 to pin 3. The input is selected on the front panel and comes in on pin 5. C10 and C11 allow the amplifier to be high frequency compensated and are adjusted to give the best Gaussian response when a 1 MHz square wave is applied. A-c is coupled from the transformer to pins 1 and 2 and drives the bridge rectifier made up of diodes CR7 through CR10. The outputs of the bridge rectifier are filtered by C14 and C15 providing the supply voltages for the output amplifier. R41 is the d-c balance control allowing the output to be adjusted for symmetry about ground. R41 is a screwdriver adjustment available from the rear panel. D-C OFFSET MODIFICATION. To convert the d-c Balance control, R41, to a d-c Offset control, remove R40 and R42, 10K 1% and replace with 2K 5% carbon resistors. R41 will now serve as a d-c offset control allowing the power amplifier output to be offset approximately ±5 vdc. It should be remembered that using an offset control limits the available peak output signal. The output will deliver 100 ma into a short circuit and 32.5 volts peak to peak into an open circuit. When terminated in 600Ω, the amplifier will deliver 30 volts peak to peak. When terminated in 50Ω, the amplifier will deliver 10 volts peak to peak. When offset +5 vdc, the output when terminated in 600Ω is only capable of swinging +10 volts peak. When offset +5 vdc and terminated in 50Ω, the output is at its positive going limit point.

BATTERY POWER SUPPLY BOARD

The battery power supply delivers + and - 6 volts d-c to a 110 or 111 from two 7-cell, 500 ma/hr rechargeable Ni-Cad batteries. The regulator circuits are similar to the regulators in the standard power supply board. Q3 is connected as a zener diode reference. The two regulators have differential amplifiers driving pass transistors. Since the on/off wafer may not be in the off position when the battery supply is removed from the instrument, switch S2 is provided to allow the batteries to be disconnected to prevent discharge.

The remaining circuitry makes up the charging circuit. The batteries are always being charged as long as S2 is on and the line cord is plugged into an a-c source. The transformer delivers a-c to pins 1 and 2. The a-c is rectified by the bridge rectifier, filtered by C1 and supplied to the charging network. Q1 is a zener diode connected transistor serving as a reference for the charge circuit. When the instrument is turned off and the line cord plugged in, the level set by R4 on the base of the pass transistor Q2 sets a trickle charge. R4 is available from the rear panel so that the charge rate can be adjusted. When the instrument is turned on, S1c places R6 in parallel with R3 to increase the charge rate to compensate for instrument current drain. Since the currents are different in a 110 and a 111, R6 is different when the battery supply is used in a 110 or a 111.

Since there is no power amplifier in the battery version of a 110 or 111, the power amplifier input and output pins (pins 3 and 4) are shorted together and the front panel attenuator delivers the selected waveform directly to the front panel connector. The jumper across the 560Ω resistor on the front panel is removed providing a 600Ω output resistance.

MODEL 110, FRONT PANEL

The Model 110 front panel board has the frequency ranging capacitors and resistors with their associated switch, the frequency dial potentiometer, the output amplifier function selector switch and attenuator potentiometer, the five fixed output connectors, and the power amplifier output connectors.

The output of the power amplifier is available on pin 19 and is coupled through R28 to the front panel. C13 attenuates those frequencies beyond the band pass of the power amplifier to insure clean waveforms. R30 is normally jumpered. The parallel resistance of R28 and R29 in series with the parallel resistance of two 49.9Ω resistors on the power supply and output amplifier board make up the parallel resisance of the power amplifier. The jumper around R30 is removed when a 600Ω output resistance is desired. The fixed amplitude triangle, sine, sync, and the two square wave outputs are fed to BNC connectors. Resistors R17, R18, and R21 set the output resistance of the sine, triangle and 5v square wave outputs. R25 and R23 attenuate and establish the output resistance of the 5 nsec. square wave output. C8, C9, C11, C12, and R24 are high frequency roll-off components to insure clean waveforms. The 10 volt peak to peak square wave is also fed to the top of the frequency dial pot. The frequency dial pot attenuates the square wave and drives the selected integrating resistor. R16 insures that a square wave is delivered to the integrator when the frequency dial is turned fully clockwise. R20 provides an initial offset current to start the 110 when the unit is first turned on.

Wafers 1 and 2 of the frequency hertz switch select the appropriate integrating capacitors and resistors for the different frequency ranges. Wafer 3 selects resistors to ground from the center arm of the frequency dial potentiometer so that the dial pot has the same resistive loading when different integrating resistors are selected. Wafer 4 selects resistors for the + input of the integrator when different integrating resistors are used so that the source current in the + and - inputs of the integrator flow in the same resistances and do not develop an offset voltage.

MODEL 111, FRONT PANEL

The 111 front panel is similar to the 110 front panel with the addition of the VCG input connectors, the frequency vernier control, the X.3-X1 switch and the ramp output connector. In addition, the dial rather than attenuating the square wave and driving the integrator, attenuates the +6 volt supply voltage and provides an input to the first VCG amplifier. The frequency vernier is returned through R30 to -6 volts. The center arm of the vernier pot provides a second input to the first VCG amplifier. In the "cal" position the vernier pot is fully clockwise and there is no vernier input to the VCG. In the CCW position of the vernier, a negative voltage is applied to the VCG and the frequency is reduced by approximately one minor dial division. The frequency hertz switch selects the appropriate integrating capacitors and resistors like the 110, however, the added X1-X.3 switch allows an added resistor to be placed in series with the selected integrating resistor when this switch is in the X.3 position. The added resistor is of such a value as to reduce the frequency to 0.3 of its X1 value.

VCG BOARD

The two VCG amplifier configurations made up of Q1 through Q10 and Q17 through Q26 are similar in operation to the integrator amplifier on the main board. The VCG amplifiers are connected as operational inverting amplifiers, however. The base of Q1 is the summing node of the first VCG amplifier. The feedback resistor is made up of R5 and R72 and there are three separate inputs. The frequency vernier voltage is present on pin 6 and applied to the summing node through R1. The frequency dial voltage is present on pin 7 and applied to the summing node through R4. Any voltage applied to the VCG input connector on the front panel is present on pin 4 and applied to the summing node through R2 and R3. The output voltage at the collectors of Q11 and Q12 is an inverted voltage level set by the algebraic sum of the applied voltages at the inputs.

The square wave from the output switch on the main board is present on pin 11 and is applied to the base of Q11 through R26. The negative going portion of the square wave turns on and saturates Q11, connecting the output of the first VCG amplifier to pin 5. During the positive going portion of the square wave, Q11 is off; however, the square wave is also coupled through R68 to the base of Q27. During the positive going portion of the square wave, Q27 is turned on and saturated, connecting the output of the second VCG amplifier to pin 5. The result is a square wave available at pin 5 whose magnitude is dependent upon the levels at the outputs of the two VCG amplifiers. The gain of the second VCG amplifier is -1; therefore, its output level is an inverted version of the output level of the first VCG amplifier which drives the second. Q12 is added in the feedback path of the first VCG amplifier and Q28 in the feedback path of the second VCG amplifier to compensate for the small drop across the saturating clamp transistors, Q11 and Q27.

R72 is the main frequency control and R42 allows the two half cycles to be made symmetrical. R13 and R53 are the d-c balance controls for the two amplifiers. R3 adjusts the proper gain of the VCG input circuitry.

When properly calibrated, the system is so well balanced that it cannot start when the machine is first turned on. The square wave output from the VCG clamp transistors on pin 5 drives the input to the integrator. R70 is added to provide an initial unbalance to allow the integrator to start. Once the machine is running, resistors R69 and R71 offset the unbalance introduced by R70 and the system is once again balanced.

RAMP CIRCUIT

The triangle wave is available on pin 1 and is offset and attenuated by resistors R28, R29, R30, R31 and R32 so that its most positive excursion is zero volts d-c and its most negative excursion is -2.5 volts. Transistors Q13 and Q14 are turned on and saturated by the negative portion of the square wave applied to their bases through R34 and R36. When turned on, Q13 and Q14 chop the positive going portion of the

offset triangle to ground. The result is a negative going 2.5 volt ramp in phase with the negative going portion of the triangle output. The ramp is delivered to pin 10 through two emitter followers, Q15 and Q16. The two opposing base to emitter voltages insure that the ramp starts at ground and the emitter followers temperature compensate each other.

SECTION IV
CALIBRATION

MODEL 110 CALIBRATION PROCEDURE

EQUIPMENT REQUIRED

1. Voltmeter, 1% accuracy, 1 mv resolution (Digital Voltmeter or equivalent).

*2. Oscilloscope, Tektronix 530 Series or equivalent.

*3. Plug-in, Tektronix type W or equivalent.

4. Plug-in, Tektronix type CA or equivalent.

5. Frequency counter, 5 digit resolution.

6. Distortion analyzer, Hewlett Packard Model 330C or equivalent.

7. Two only 50 ohm cables with BNC connectors, 50 ohm termination.

*If Tektronix scope and type W are not available, any peak reading device with an accuracy of 1% or better can be used.

Remove cover from instrument.

POWER SUPPLY BOARD (REAR ETCHED CIRCUIT BOARD). Two 100 uf bypass capacitors are located in the bottom of the instrument; these are filter capacitors for the +6v and -6v power supplies. The capacitor toward the rear of the instrument is in the +6v supply and the other is in the -6v supply. The capacitor leads are convenient voltage test points. Connect an appropriate indicating device between the end marked + of the rear 100 uf capacitor and circuit ground. Adjust R24 for +6.00 volts ±1 mv. Move the indicating device to the other capacitor between the end marked - and circuit ground. Adjust R9 for -6.00 volts ±1 mv. To compensate for the effects of interaction, repeat these adjustments.

There is no adjustment in the +24 and -24 volt supplies.

Typical 120 cycle ripple in the ±6 volt supplies is 250 μv.

Typical 120 cycle ripple in the ±24 volt supplies is 250 mv.

POWER AMPLIFIER (REAR ETCHED CIRCUIT BOARD). Set output amplifier function selector front panel switch on square wave. Set attenuator fully clockwise. Observe front panel output GR connector on oscilloscope, open circuited and adjust R31 for a 32.5 volt p-p square wave.

Adjust square wave with output attenuator fully counter-clockwise for symmetry about ground with R41. Adjust 1 MHz square wave into open circuit with C11 for an optimum square wave with no overshoot. Check for less than 100 nsec risetime. Check for 30v into 600 ohms, and 10v into 50 ohms.

MAIN BOARD (SECOND ETCHED CIRCUIT BOARD FROM FRONT PANEL). 1. Rotate dial to extreme clockwise position. Connect a lead between the center arm of the dial pot and circuit ground. Install 100K resistor between Pin 1 and Pin 3 of the main board. Observe integrator output with appropriate indicating device at junction of R17 and R18. Adjust R8 for zero volts at X100, extreme bottom of dial. Remove jumper wire and 100K resistor.

2. Using Tektronix scope and type W plug-in, observe triangle at front panel connector, open circuit. Adjust R78 in switch set for the triangle break at exactly -2.50v. Use comparison voltage on type W plug-in and adjust R77 for the triangle break at exactly +2.50v. To compensate for effect of interaction, repeat adjustments.

3. Observe 15 nsec square wave for leading edge spikes with 50 ohm cable terminated into 50 ohms. Adjust R104 for + and - 2.5 volts ±1 mv. Adjust R99 for symmetry about ground. Tolerance on spikes is 5% of total p-p amplitude. Set range switch X100, rotate dial, measuring frequency at 5 nsec BNC connector with 50 ohm cable and 50 ohm termination and counter. Set dial reading to 10 (1000 Hz) and tighten setscrew. Set dial at 1 and adjust R8 for time symmetry.

4. Observe 5 nsec square wave output on oscilloscope to be free of excessive leading edge spikes, X100K top of freq dial, using 50 ohm cable terminated in 50 ohm.

SINE WAVEFORM ADJUSTMENTS (SECOND ETCHED BOARD FROM FRONT PANEL) Place main board on extender cable. Observe sine at BNC connector, open circuited.

1. Using Tektronix scope and type W plug-in, set frequency dial at 10, range X100.

Adjust R64 for sine out of ±2.5 volts. Adjust R60 for sine symmetry about ground. Using distortion analyzer, adjust R20, R24, R30, R33, R38, R41, R46, and R49 for minimum harmonic distortion. Readjust R64 and R60 for amplitude and symmetry about ground. Typical harmonic distortion is 0.12%.

2. Set dial at 1. Measure distortion. Typical distortion is 0.2%.

CHECK RANGES

Check all fixed ranges for frequency tracking. Trim resistors have been installed on individual ranges for tracking. Adjust C5 for proper tracking on X10K range. A trim resistor has been installed between position 3 and position 5 on wafer 1 of range switch for proper tracking on X1K range. Adjust C1 for proper tracking on X100K range.

MODEL 111 CALIBRATION PROCEDURE

EQUIPMENT REQUIRED

1. Voltmeter, 1% accuracy, 1 mv resolution (Digital Voltmeter or equivalent).

*2. Oscilloscope, Tektronix 530 Series or equivalent.

*3. Plug-in, Tektronix type W or equivalent.

4. Plug-in, Tektronix type CA or equivalent.

5. Frequency counter, 5 digit resolution.

6. Distortion analyzer HP Model 330C or equivalent.

7. Two 50 ohm cables with BNC connectors, 50 ohm termination.

*If Tektronix scope and type W plug-in are not available, any peak reading device with an accuracy of 1% or better can be used.

Remove cover from instrument.

POWER SUPPLY BOARD (REAR ETCHED CIRCUIT BOARD). Two 100 uf bypass capacitors are located in the bottom of the instrument which are filter capacitors for the +6 v and -6 v power supplies. The capacitor toward the rear of the instrument is in the +6 v supply, and the other is in the -6 v supply. The capacitor leads are convenient voltage test points. Connect an appropriate indicating device between the end marked + of the rear 100 uf capacitor and circuit ground. Adjust R24 for +6.00 volts ±1 mv. Move the indicating device to the other capacitor between the end marked - and circuit ground. Adjust R9 for -6.00 volts ±1 mv. To compensate for the effects of interaction, repeat these adjustments.

There is no adjustment in the + and - 24 volt supplies.

Typical 120 cycle ripple, ±6 volt supplies is 250 μv.

Typical 120 cycle ripple, ±24 volt supplies is 250 mv.

POWER AMPLIFIER (REAR ETCHED CIRCUIT BOARD). Set output amplifier function selector (front panel) switch on square wave. Set attenuator fully clockwise. Observe front panel output GR connector on oscilloscope open circuited and adjust R31 for a 32.5 volt p-p square wave.

Adjust square wave with output attenuator fully counterclockwise for symmetry about ground with R41. Adjust 1 MHz square wave into open circuit with C11 for optimum square wave with

no overshoot. Check for less than 100 nsec risetime. Check for 30v into 600 ohms, and 10v into 50 ohms.

MAIN BOARD (SECOND ETCHED CIRCUIT BOARD FROM FRONT PANEL) 1. Set at X100 extreme bottom of frequency dial. Use jumper to short pin 5, VCG board to circuit ground. Install 100K resistor between Pin 1 and Pin 3 of the main board. Observe integrator output with appropriate indicating device at junction of R17 and R18. Adjust R8 for zero volts. Remove jumper wire and 100 K resistor.

2. Using Tektronix scope and type W plug-in, observe triangle at front panel connector, open circuit. Adjust R78 in switch set for the triangle break at exactly -2.50v (use comparison voltage on type W plug-in). Adjust R77 for the triangle break at exactly +2.50v. To compensate for effects of interaction, repeat adjustments.

3. Observe 15 nsec square wave for leading edge spikes with 50 ohm cable terminated into 50 ohm. Adjust R104 for + and - 2.5 volts ±1 mv. Adjust R99 for symmetry about ground. Tolerance on spikes is 5% of total p-p amplitude.

4. Observe that 5 nsec square wave output on oscilloscope is free of excessive leading edge spikes, (X100K top of frequency dial, using 50 ohm cable terminated into 50 ohms).

SINE WAVEFORM ADJUSTMENTS (SECOND ETCHED BOARD FROM FRONT PANEL)

1. Using Tektronix scope and type W plug-in, set frequency dial at 10, range X100. Place main board on extender cable. Observe sine at BNC connector.

Adjust R64 for sine wave out of ±2.5 volts ±1 mv. Adjust R60 for sine symmetry about ground. Using distortion analyzer, adjust R20, R24, R30, R33, R38, R41, R46, and R49 for minimum harmonic distortion. Readjust R64 and R60 for amplitude and symmetry about ground. Typical harmonic distortion 0.12%.

2. Set dial at 1. Measure distortion. Typical distortion is 0.2%.

VCG BOARD FREQUENCY (THIRD ETCHED BOARD FROM FRONT PANEL)

1. Set dial to extreme clockwise position. Using jumper, short VCG dial input (pin 7, VCG board) to signal ground (insure that vernier is fully clockwise). Observe output of first VCG amplifier at junction of R22 and R23 in pushpull emitter followers and adjust R13 for zero volts. Observe second VCG amplifier at junction of R64 and R65 and adjust R53 for zero volts. This adjustment insures that the amplifiers can be balanced and sets an approximate balance for adjusting top of dial. Remove jumpers.

2. Observe Pin 7 (VCG board). Using digital voltmeter set dial for +5.75 volts ±2 mv. Tighten set screw in dial with dial reading 10. Set range switch at X100, dial at 10. Adjust R71 for 1,000 Hz, adjust R42 for time symmetry (0.5 ms). To compensate for effects of

interaction, repeat adjustments. Do not reset symmetry in integrator. Set dial at 1. Readjust R13 and R53 for time symmetry and 100 Hz. It may be necessary to move back and forth from top to bottom of dial several times until optimum settings are obtained.

Monitor voltage at center arm of dial pot and insure that VCG is tracking. Use the following chart:

X100 RANGE

Dial Pot - Center Arm	Frequency
+5.75 volts	1000 Hz
5.175 volts	900 Hz
4.600 volts	800 Hz
4.025 volts	700 Hz
3.45 volts	600 Hz
2.875 volts	500 Hz
2.3 volts	400 Hz
1.725 volts	300 Hz
1.150 volts	200 Hz
0.575 volts	100 Hz

Tolerance, normal dial accuracy. If the VCG tracks, check dial for proper tracking.

To adjust VCG in, set dial at 5 and monitor frequency, range switch at X100, frequency 500 Hz Apply +1.00 volts to VCG in on front panel and adjust R3 for an output frequency of 700 Hz.

Rotate vernier fully counterclockwise and observe that frequency decreases approximately one minor dial division. Return vernier fully clockwise.

RAMP ADJUSTMENT. Observe ramp output at BNC connector with 50 ohm cable terminated into 50 ohm load. Adjust R30 so that signal is neither nor , but is .

Adjust R32 for -2.5 volts peak ramp output.

CHECK RANGES. Check all fixed ranges for frequency tracking. Trim resistors have been installed on individual ranges for tracking. Adjust C5 for proper tracking on X10K range. A trim resistor has been installed between position 3 and position 5 on wafer 1 of range switch for proper tracking on X1K range. Adjust C1 for proper tracking on X100K range.

SECTION V
PARTS LIST

GENERAL

This section contains a list of replaceable electronic parts and assemblies in the equipment; structural items and hardware such as screws and nuts are not included.

PARTS LIST ARRANGEMENT

The parts list starts with the chassis assembly as figure 5-1, which lists components found on the chassis, as well as the major modular components.

LIST OF MANUFACTURERS

The MANUFACTURER column of the parts list uses brief descriptions; the full names are given below.

Allen Bradley	Allen Bradley, Milwaukee, Wis.
ARCO	Arco Electronics, Great Neck, N.Y.
CDE	Cornell Dubilier, Director of Federal Pacific Electric Co. Newark, N.J.
Continental	Continental-Wirt Electronics Corp, Philadelphia, Pa.
CRL	Centralab, Division of Globe-Union, Milwaukee, Wis.
Electra	Electra Manufacturing Co., Independance, Kansas.
Elpac	Elpac Inc., Fullerton, California.
Fairchild	Fairchild Semiconductor Corp., Palo Alto, California
Gen Elect	General Electric, Semiconductor Products Division, Buffalo, N.Y.
Johnson	E.F. Johnson Co., Waseca, Minn.

Kings	Kings Electronics Co. Inc., Tuckahoe, N.Y.
Motorola	Motorola Semiconductor Products, Phoenix, Ariz.
Nashville	Nashville Electronics, Inc., Nashville, Tenn.
RCA	RCA Semiconductor Division, Somerville, N.J.
Smith	H.H. Smith, Inc., Brooklyn, N.Y.
Sprague	Sprague Electric Co., North Adams, Mass.
Stackpole	Stackpole Carbon Co., St. Marys, Pa.
TRW	TRW Electronics, Inc., El Segundo, California.
USECO	USECO, Inc., Mt. Vernon, N.Y.
Wakefield	Wakefield Engineering, Inc., Wakefield, Mass.

MATCHED OR PAIRED PARTS

Prior to ordering or replacing electronic components in the equipment, refer to the notes regarding matched or paired parts on the schematic diagrams in Section VI.

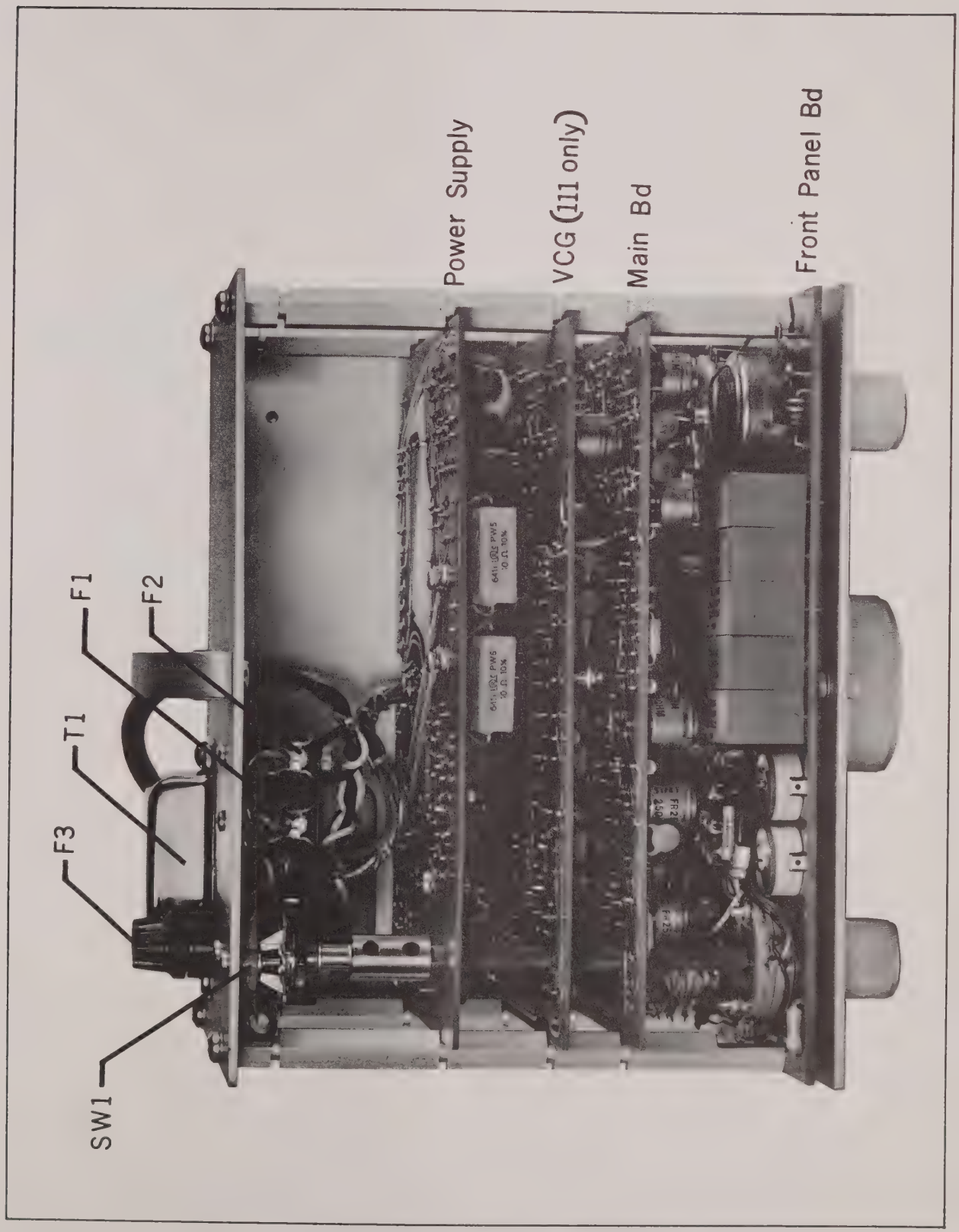


Figure 5-1. Chassis Assembly.

CIRCUIT REFERENCE	PART NO.	DESCRIPTION	QTY PER ASSY	MANUFACTURER
C1, C2*	TL1135	CAPACITOR, Electrolytic, 12v 100 mfd	2	Sprague
	013-5200	CONNECTOR PIN	20	Elco
	5201-0213	CONNECTOR PIN	39	Elco
F1, F2		FUSE, 1/4 AMP, SLO-BLO	2	Littelfuse
F3		FUSE, 3/4 AMP, SLO-BLO	1	Littelfuse
SW1	110SW2	SWITCH	1	Wavetek
	110-100C	MOTHER BOARD	1	Wavetek
T1	110-500	TRANSFORMER	1	Wavetek
		Chassis Assembly	1	Wavetek
	110-102	Main Board Assembly	1	Wavetek
	110-101	Front Panel Assembly (Model 110)	1	Wavetek
	111-101	Front Panel Assembly (Model 111)	1	Wavetek
	110B-104*	Battery Power Assembly	1	Wavetek
	110-104	Power Supply and Output Amplifier Assembly	1	Wavetek
	111-103	VCG Board Assembly	1	Wavetek

*Not visible on illustration.

Chassis Assembly Parts List

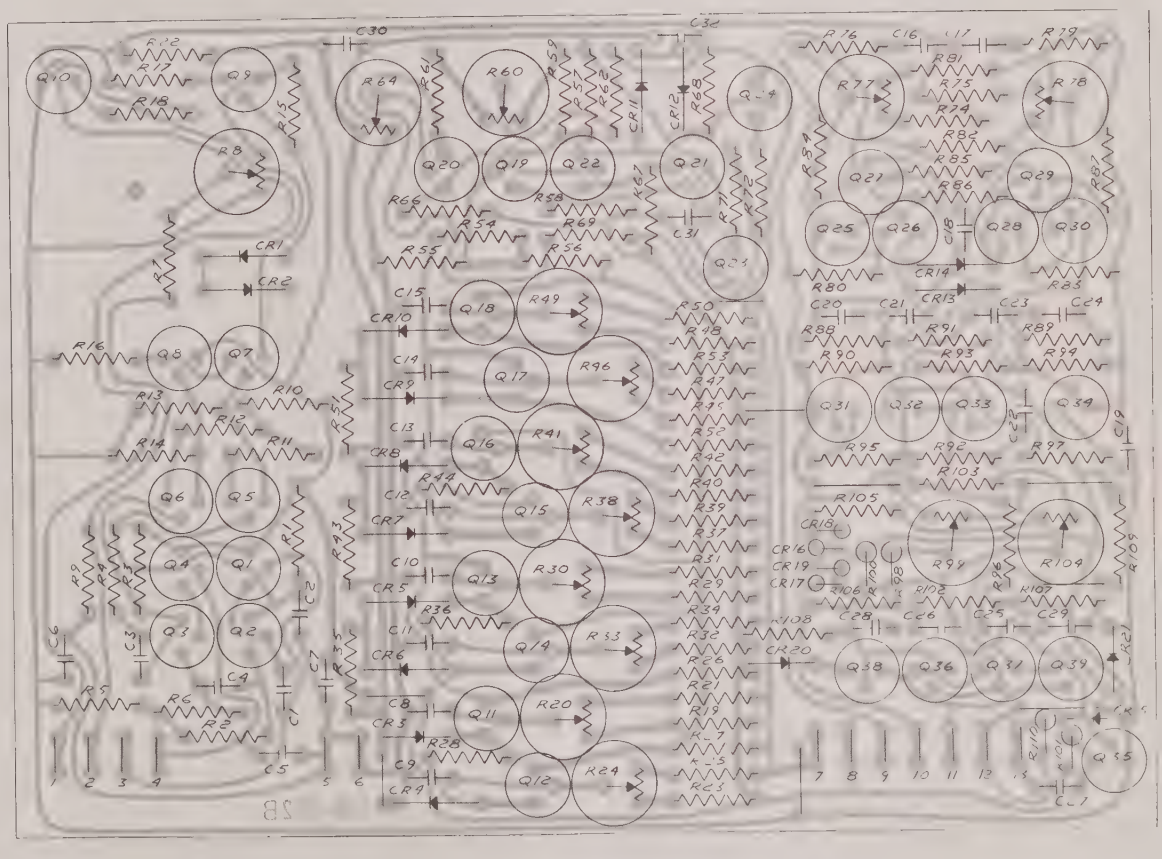


Figure 5-2. Main Board Assembly.

CIRCUIT REFERENCE	PART NO.	DESCRIPTION	QTY PER ASSY	MANUFACTURER
C1, C2	DD101	CAPACITOR, Ceramic, 1000v 100 mmf	2	CRL
C3	DD391	CAPACITOR, Ceramic, 1000v 390 mmf	1	CRL
C4, C5, C8, C9, C10, C11, C12, C13, C14, C15,	CCD102	CAPACITOR, Ceramic, 1000v 1000 mmf	10	ARCO
C6, C7, C18, C19, C31, C32	HY320	CAPACITOR, Ceramic, 0.1 mfd	6	Sprague
C16, C17	DD221	CAPACITOR, Ceramic, 1000v 220 mmf	2	CRL
C20, C24, C25	DD220	CAPACITOR, Ceramic, 1000v 22 mmf	3	CRL
C21, C23	DD470	CAPACITOR, Ceramic, 1000v 47 mmf	2	CRL
C22	DD100	CAPACITOR, Ceramic, 1000v 10 mmf	1	CRL
C26	DD050	CAPACITOR, Ceramic, 1000v 5 mmf	1	CRL
C27, C28, C29	DD471	CAPACITOR, Ceramic, 1000v 470 mmf	3	CRL
C30	DD330	CAPACITOR, Ceramic, 1000v 33 mmf	1	CRL
CR1 thru CR21	1N4009	DIODE	21	Gen. Elect.
Q1 thru Q4	2N3856	TRANSISTOR	4	Gen. Elect.
Q5, Q6, Q10, Q21, Q22, Q24, Q25, Q28, Q29, Q31, Q33, Q37, Q38	2N3640	TRANSISTOR	13	Fairchild
Q7, Q8, Q9, Q11, Q13, Q15, Q17, Q23, Q26, Q27, Q30, Q32, Q34, Q35, Q36, Q39, Q19, Q20	2N3646	TRANSISTOR	18	Fairchild
Q12, Q14, Q16, Q18	2N3638	TRANSISTOR	4	Fairchild

Main Board Assembly Parts List (Sheet 1 of 4).

CIRCUIT REFERENCE	PART NO.	DESCRIPTION	QTY PER ASSY	MANUFACTURER
R1, R3, R7	RN60D	RESISTOR, Metal Film, 1/4W 1% 110000 ohm	2	Electra
R2, R6, R15, R36, R54, R56	RN60D	RESISTOR, Metal Film, 1/4W 1% 1000 ohm	6	Electra
R4	RN60D	RESISTOR, Metal Film, 1/4W 1% 196 ohm	1	Electra
R5,	RN60D	RESISTOR, Metal Film, 1/4W 1% 46400 ohm	1	Electra
R21, R23, R31 R32, R39, R40 R45, R47, R48 R50, R52, R53	RN60D	RESISTOR, Metal Film, 1/4W 1% 4640 ohm	12	Electra
R8, R64, R99	FR1032M	POTENTIOMETER, Single Turn, 10000 ohm	3	Allen Bradley
R10	RC20GF302J	RESISTOR, Carbon, 1/2W 5% 3000 ohm	1	Stackpole
R11, R12	RN60D	RESISTOR, Metal Film, 1/4W 1% 100 ohm	2	Electra
R13, R14, R37, R42	RN60D	RESISTOR, Metal Film, 1/4W 1% 3830 ohm	4	Electra
R16, R102, R106, R107	RC20GF101K	RESISTOR, Carbon, 1/2W 10% 100 ohm	4	Stackpole
R17, R18, R71, R72	RC20GF150K	RESISTOR, Carbon, 1/2W 10%, 15 ohm	4	Stackpole
R19, R25	RN60D	RESISTOR, Metal Film, 1/4W 1% 2870 ohm	2	Electra
R20, R24, R30, R33, R38, R41, R46, R49, R60, R77, R78, R104	FR251M	POTENTIOMETER, Single Turn, 250 ohm	12	Allen Bradley
R26, R27, R44, R105	RN60D	RESISTOR, Metal Film, 1/4W 1% 511 ohm	4	Electra

Main Board Assembly Parts List (Sheet 2 of 4).

CIRCUIT REFERENCE	PART NO.	DESCRIPTION	QTY PER ASSY	MANUFACTURER
R28, R103	RN60D	RESISTOR, Metal Film, 1/4W 1% 316 ohm	2	Electra
R29, R34, R63	RN60D	RESISTOR, Metal Film, 1/4W 1% 3160 ohm	3	Electra
R35, R59, R61, R74, R75	RN60D	RESISTOR, Metal Film, 1/4W 1% 825 ohm	5	Electra
R43	RN60D	RESISTOR, Metal Film, 1/4W 1% 1620 ohm	1	Electra
R51	RN60D	RESISTOR, Metal Film, 1/4W 1% 100 ohm	1	Electra
R55	RC20GF151K	RESISTOR, Carbon, 1/2W 10% 150 ohm	1	Stackpole
R57, R69	RN60D	RESISTOR, Metal Film, 1/4W 1% 6980 ohm	2	Electra
R58, R66	RN60D	RESISTOR, Metal Film, 1/4W 1% 10000 ohm	2	Electra
R62	RC20GF472K	RESISTOR, Carbon, 1/2W 5% 4700ohm	1	Stackpole
R65, R81, R82	RN60D	RESISTOR, Metal Film, 1/4W 1% 2000 ohm	3	Electra
R67	RC20GF151K	RESISTOR, Carbon, 1/2W 10% 150 ohm	1	Stackpole
R68	RC20GF102K	RESISTOR, Carbon, 1/2W 10% 1000 ohm	1	Stackpole
R91, R93	RC20GF470K	RESISTOR, Carbon, 1/2W 10% 47 ohm	2	Stackpole
R76, R79	RC20GF911J	RESISTOR, Carbon, 1/2W 5% 910 ohm	2	Stackpole
R80, R83	RC20GF332J	RESISTOR, Carbon, 1/2W 5% 3300 ohm	2	Stackpole
R84, R87	RC20GF471K	RESISTOR, Carbon, 1/2W 10% 470 ohm	2	Stackpole
R85, R86	RC20GF472K	RESISTOR, Carbon, 1/2W 10% 4700 ohm	2	Stackpole
R88, R89, R101	RC20GF102K	RESISTOR, Carbon, 1/2W 10% 1000 ohm	3	Stackpole
R90, R94	RC20GF561K	RESISTOR, Carbon, 1/2W 10% 560 ohm	2	Stackpole
R92	RC20GF620K	RESISTOR, Carbon, 1/2W 10% 62 ohm	1	Stackpole
R95, R97	RC20GF100K	RESISTOR, Carbon, 1/2W 10% 10 ohm	2	Stackpole

Main Board Assembly Parts List (Sheet 3 of 4).

CIRCUIT REFERENCE	PART NO.	DESCRIPTION	QTY PER ASSY	MANUFACTURER
R96	RC20GF222K	RESISTOR, Carbon, 1/2W 10% 2200 ohm	1	Stackpole
R98,	RN60D	RESISTOR, Metal Film, 1/4W 1% 21500 ohm	1	Electra
R108, R109	RC20GF122K	RESISTOR, Carbon, 1/2W 10% 1200 ohm	2	Stackpole
R110	RC20GF103K	RESISTOR, Carbon, 1/2W 10% 10000 ohm	1	Stackpole
	05-3303	SOCKET, TRANSISTOR	6	Elco
R9, R80, R83	RN60D	RESISTOR, Metal Film, 1/4W 1% 3010 ohm	3	Electra
R100	RN60D	RESISTOR, Metal Film, 1/4W 1% 1960 ohm	1	Electra

Main Board Assembly Parts List (Sheet 4 of 4).

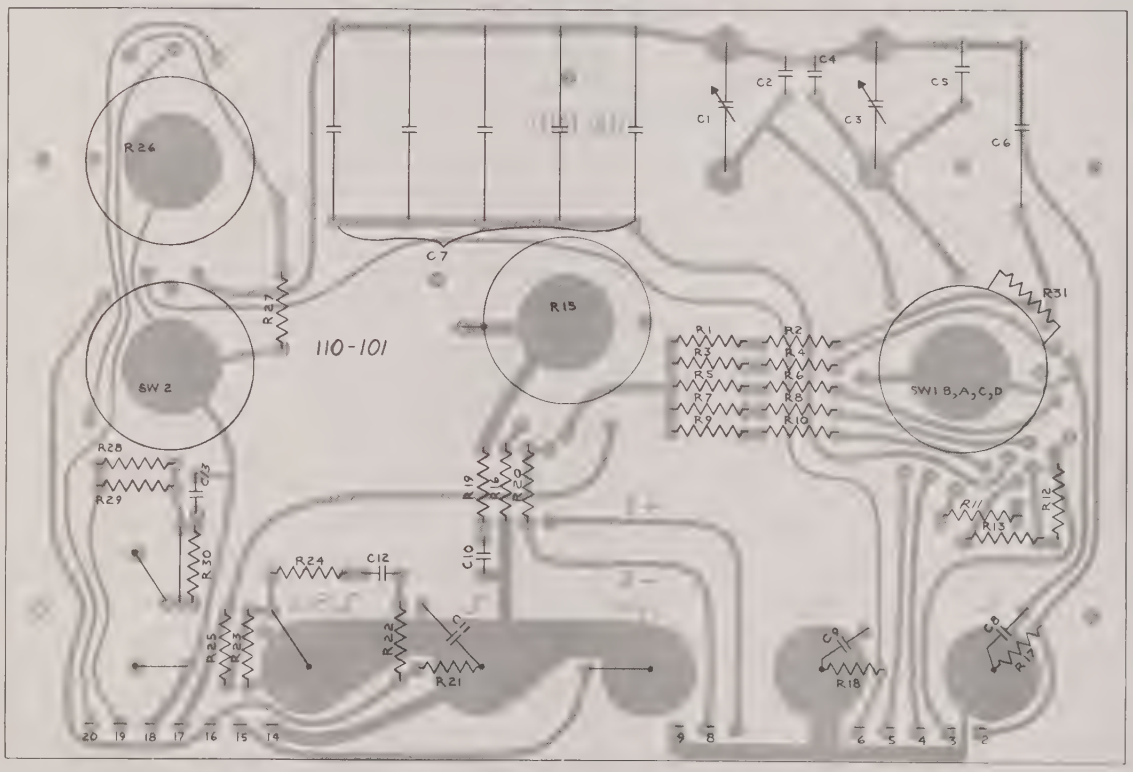


Figure 5-3. Front Panel Assembly (Model 110).

CIRCUIT REFERENCE	PART NO.	DESCRIPTION	QTY PER ASSY	MANUFACTURER
C1, C3	825AZ	CAPACITOR, Variohm, 4.5 to 25 mmf	2	CRL
C2	DM15-820J	CAPACITOR, Silver Mica, 82 mmf	1	Arco
C4	DM15-560J	CAPACITOR, Silver Mica, 56 mmf	1	Arco
C5	DM15-911F	CAPACITOR, Silver Mica, 910 mmf	1	Arco
C6	HY320	CAPACITOR, Ceramic Disc, 0.1 mfd	1	Sprague
C7	ZX-3022	CAPACITOR, Mylar, 5 x 2 mfd	1	Elpac
C8	DD681	CAPACITOR, Ceramic Disc, 680 mmf	1	CRL
C9	DD102	CAPACITOR, Ceramic Disc, 1000 mmf	1	CRL
C10	DD331	CAPACITOR, Ceramic Disc, 330 mmf	1	CRL
C11, C13	DD221	CAPACITOR, Ceramic Disc, 220 mmf	2	CRL
C12	DD470	CAPACITOR, Ceramic Disc, 47 mmf	1	CRL
R2, R6	RN60D	RESISTOR, Metal Film, 1/4W 1% 4640 ohm	2	Electra
R4, R7	RN60D	RESISTOR, Metal Film, 1/4W 1% 46400 ohm	2	Electra
R10	RN60D	RESISTOR, Metal Film, 1/4W 1% 464000 ohm	1	Electra
R11, R25	RC20GF471K	RESISTOR, Carbon, 1/2W 10%, 470 ohm	2	Stackpole
R12	RN60D	RESISTOR, Metal Film, 1/4W 1% 42200 ohm	1	Electra
R13	RN60D	RESISTOR, Metal Film, 1/4W 1% 422000 ohm	1	Electra
R15	JAIN104P-102UA	POTENTIOMETER, 1000 ohm	1	Allen Bradley
R16	RN60D	RESISTOR, Metal Film, 1/4W 1% 21.5 ohm	1	Electra
R17, R18, R21, R28, R29	RN60D	RESISTOR, Metal Film, 1/4W 1% 49.9 ohm	5	Electra
R19, R24	RC20GF270K	RESISTOR, Carbon, 1/2W 10% 27 ohm	2	Stackpole

Front Panel Assembly Parts List (Model 110) (Sheet 1 of 2).

CIRCUIT REFERENCE	PART NO.	DESCRIPTION	QTY PER ASSY	MANUFACTURER
R20	RC20GF123K	RESISTOR, Carbon, 1/2W 10% 12000 ohm	1	Stackpole
R22	RC20GF103K	RESISTOR, Carbon, 1/2W 10% 10000 ohm	1	Stackpole
R23	RC20GF560K	RESISTOR, Carbon, 1/2W 10% 56 ohm	1	Stackpole
R26	111-R2	POTENTIOMETER, 500 ohm	1	Wavetek
R30	RC20GF561K	RESISTOR, Carbon, 1/2W 10% 560 ohm	1	Stackpole
SW1	110-SW1	SWITCH	1	Wavetek
SW2	110-SW2	SWITCH	1	Wavetek
		WAFER, From 103SW2	1	Wavetek
R31		RESISTOR, Carbon, 1/2W 10% Selected Value	1	

Front Panel Assembly Parts List (Model 110) (Sheet 2 of 2).

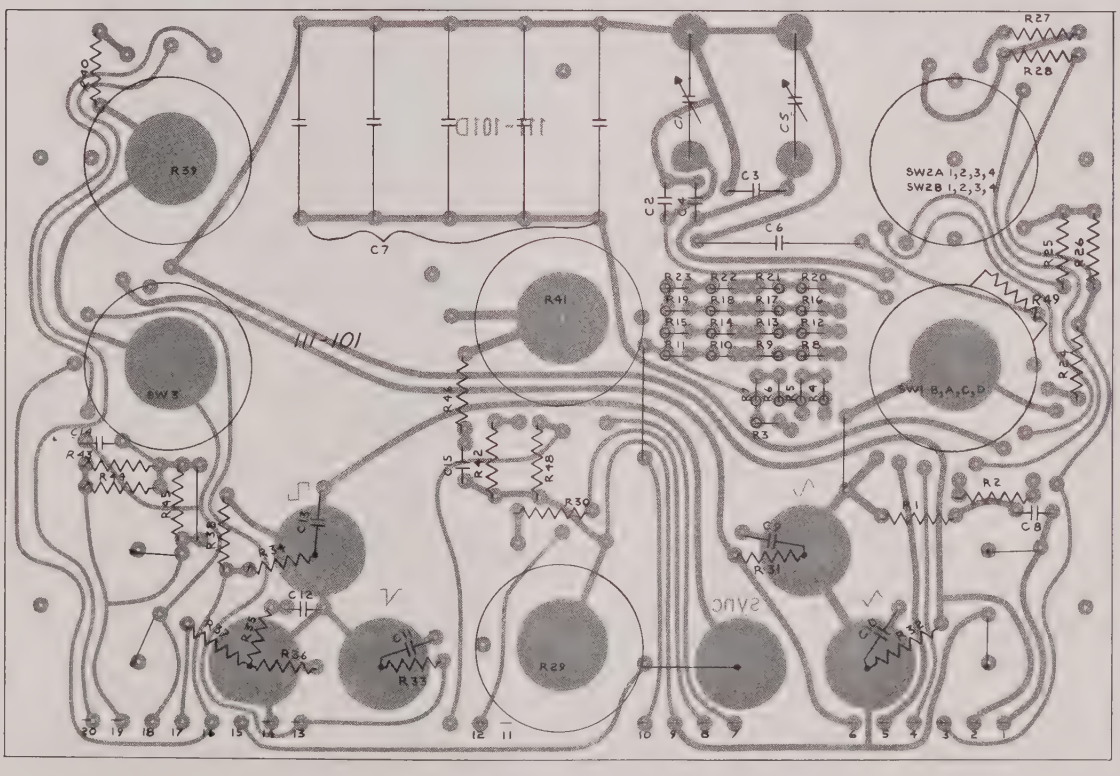


Figure 5-4. Front Panel Assembly (Model 111).

CIRCUIT REFERENCE	PART NO.	DESCRIPTION	QTY PER ASSY	MANUFACTURER
C1, C5	825AZ	CAPACITOR, Variohm 4.5 to 25 mmf	2	CRL
C2	DM15-680J	CAPACITOR, Silver Mica, 15v 68 mmf 5%	1	ARCO
C3	DM15-911F	CAPACITOR, Silver Mica, 15v 910 mmf 1%	1	ARCO
C4	DM15-560J	CAPACITOR, Silver Mica, 15v 56 mmf 5%	1	ARCO
C6	1PJ-104F	CAPACITOR, Polystyrene, 100v 0.1 mfd	1	ARCO
C7	ZX-3022	CAPACITOR, Mylar, 5 x 2.0 mfd	1	Elpac
C8	DD471	CAPACITOR, Ceramic, 1000v 470 mmf	1	CRL
C9	CCD102	CAPACITOR, Ceramic, 1000v 1000 mmf	1	ARCO
C10, C11	DD681	CAPACITOR, Ceramic, 1000v 680 mmf	2	CRL
C12	DD470	CAPACITOR, Ceramic, 1000v 47 mmf	1	CRL
C13, C14	DD221	CAPACITOR, Ceramic, 1000v 220 mmf	2	CRL
C15	DD331	CAPACITOR, Ceramic, 1000v 330 mmf	1	CRL
R1, R37	RC20GF471K	RESISTOR, Carbon, 1/2W 10% 470 ohm	2	Stackpole
R2	RC20GF221K	RESISTOR, Carbon, 1/2W 10% 220 ohm	1	Stackpole
R3	RN60D	RESISTOR, Metal Film, 1/4W 1% 4320 ohm	1	Electra
R5, R13	RN60D	RESISTOR, Metal Film, 1/4W 1% 6980 ohm	2	Electra
R9, R17, R25	RN60D	RESISTOR, Metal Film, 1/4W 1% 69800 ohm	3	Electra
R11, R19, R26	RN60D	RESISTOR, Metal Film, 1/4W 1% 30100 ohm	3	Electra
R15, R7	RN60D	RESISTOR, Metal Film, 1/4W 1% 3010 ohm	2	Electra
R21, R27	RN60D	RESISTOR, Metal Film, 1/4W 1% 698000 ohm	2	Electra
R23, R28	RN60D	RESISTOR, Metal Film, 1/4W 1% 301000 ohm	2	Electra
R24	RC20GF302K	RESISTOR, Carbon, 1/2W 10% 3000 ohm	1	Stackpole

Front Panel Assembly Parts List (Model 111) (Sheet 1 of 2).

CIRCUIT REFERENCE	PART NO.	DESCRIPTION	QTY PER ASSY	MANUFACTURER
R29, R39	111-R2	POTENTIOMETER, Single Turn, 500 ohm	2	Wavetek
R30	RC20GF562K	RESISTOR, Carbon, 1/2W 10% 5600 ohm	1	Stackpole
R31, R32, R33, R34 R43, R44	RN60D	RESISTOR, Metal Film 1/4W 1% 49.9 ohm	6	Electra
R35, R46	RC20GF270K	RESISTOR, Carbon, 1/2W 10% 27 ohm	2	Stackpole
R36	RC20GF560K	RESISTOR, Carbon, 1/2W 10% 56 ohm	1	Stackpole
R38	RC20GF103K	RESISTOR, Carbon, 1/2W 10% 10K	1	Stackpole
R41	JAIN104P-102UA	POTENTIOMETER, Single Turn, 1000 ohm	1	Allen Bradley
R42	RN60D	RESISTOR, Metal Film, 1/4W 1% 21.5 ohm	1	Electra
R45	RC20GF561K	RESISTOR, Carbon, 1/2W 10% 560 ohm	1	Stackpole
R48	RN60D	RESISTOR, Metal Film, 1/4W 1% 8250 ohm	1	Electra
SW1	110-SW1	SWITCH	1	Wavetek
SW2A, SW2B		WAFER, From 104-SW3	2	Wavetek
SW3	110-SW2	SWITCH	1	Wavetek
	UG657/U	CONNECTOR, BNC	6	Kings
	114-3200	CONNECTOR, PIN	20	Elco
	111-103	BINDING POST	4	Johnson
	1414-8	SOLDER LUG	1	Smith

Front Panel Assembly Parts List (Model 111) (Sheet 2 of 2).

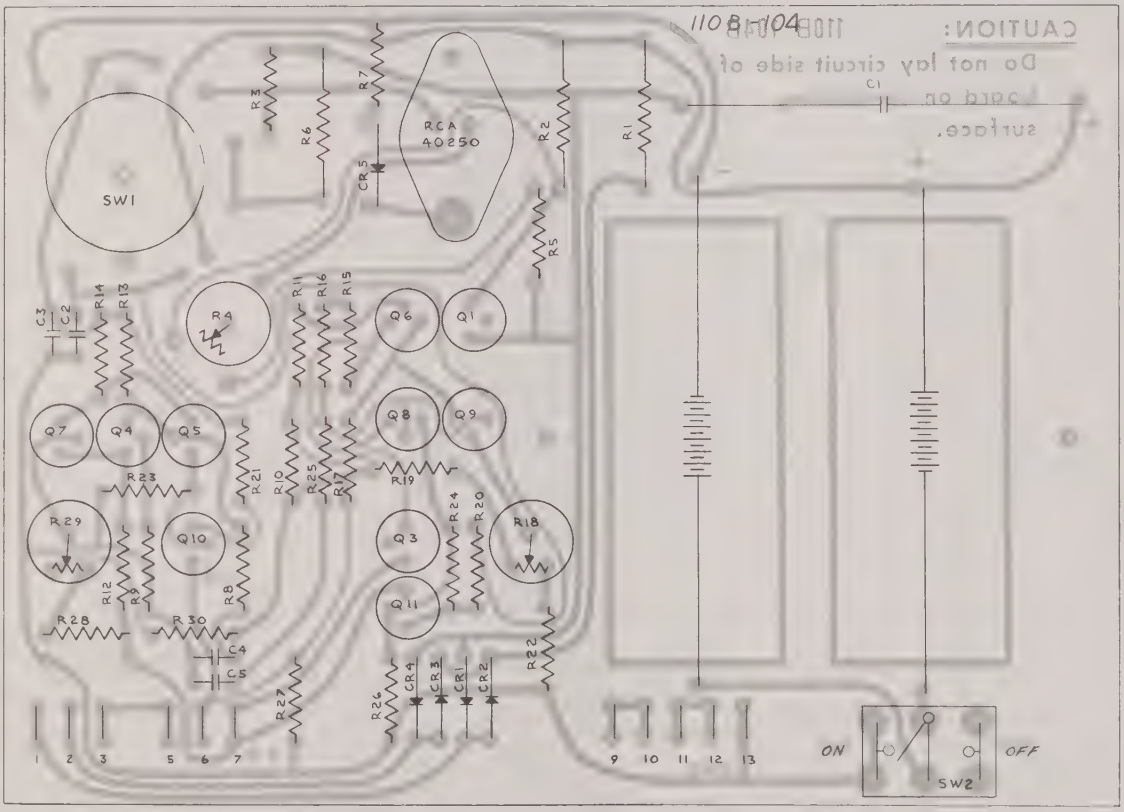


Figure 5-5. Battery Power Supply Assembly.

CIRCUIT REFERENCE	PART NO.	DESCRIPTION	QTY PER ASSY	MANUFACTURER
B1, B2	7/BH500-Y5652	BATTERY, Rechargeable ni-cad	2	Eveready
C1	BR500-50	CAPACITOR, Electrolytic, 50v 500 mfd	1	Sprague
C2, C3	H 320	CAPACITOR, Ceramic Disc, 12v 0.1 mfd	2	Sprague
C4, C5	DD331	CAPACITOR, Ceramic Disc, 1000v	2	CRL
CR1, CR2, CR3, CR4	PS5666	DIODE	4	TRW
CR5	1N3193A	DIODE	1	RCA
Q1, Q3, Q4 Q7, Q8, Q10	2N3638	TRANSISTOR	6	Fairchild
Q2	40250	TRANSISTOR	1	RCA
Q5, Q6, Q9	2N3646	TRANSISTOR	3	Fairchild
Q11	2N3567	TRANSISTOR	1	Fairchild
R1	RC42GF390J	RESISTOR, W.W., 5W, 10% 39 ohm	1	Stackpole
R4, R18, R29	FR251-M	POTENTIOMETER, Single Turn, 250 ohm	3	Allen Bradley
R5	RC20GF681J	RESISTOR, Carbon, 1/2W 5% 680 ohm	1	Stackpole
R6	RC42GF47R0J	RESISTOR, Carbon, 2W 5% 47 ohm (Model 110 only)	1	Stackpole
R6	RC42GF39ROJ	RESISTOR, Carbon, 39 ohm (Model 111 only)	1	Stackpole
R7, R20, R21	RC07GF100J	RESISTOR, Carbon, 1/4W 5% 10 ohm	3	Stackpole
R8, R14, R15, R25	RC20GF101K	RESISTOR, Carbon, 1/2W 10% 100 ohm	4	Stackpole
R9	RN60D	RESISTOR, Metal Film, 1/4W 1% 2370 ohm	1	Electra
R10	RN60D	RESISTOR, Metal Film, 1/4W 1% 2870 ohm	1	Electra
R11, R22	RN60D	RESISTOR, Metal Film, 1/4W 1% 100 ohm	2	Electra
R12	RC20GF332K	RESISTOR, Carbon, 1/2W 10% 3300 ohm	1	Stackpole
R13, R16	RC20GF821K	RESISTOR, Carbon, 1/2W 10% 820 ohm	2	Stackpole
R17, R24	RC20GF302K	RESISTOR, Carbon, 1/2W 10% 3000 ohm	2	Stackpole

Battery Power Supply Assembly Parts List (Sheet 1 of 2).

CIRCUIT REFERENCE	PART NO.	DESCRIPTION	QTY PER ASSY	MANUFACTURER
R19	RN60D	RESISTOR, Metal Film, 1/4W 1% 2000 ohm	1	Electra
R23, R26	RC20GF123K	RESISTOR, Carbon, 1/2W 10% 12000 ohm	2	Stackpole
R27	RC42GF821K	RESISTOR, Carbon, 2W 10% 820 ohm	1	Stackpole
R28, R30	RN60D	RESISTOR, Metal Film, 1/4W 1% 4640 ohm	2	Electra
SW1		SWITCH, 3 Pole	1	CTS
SW2		SWITCH, DPDT	1	Continental

Battery Power Supply Assembly Parts List (Sheet 2 of 2).

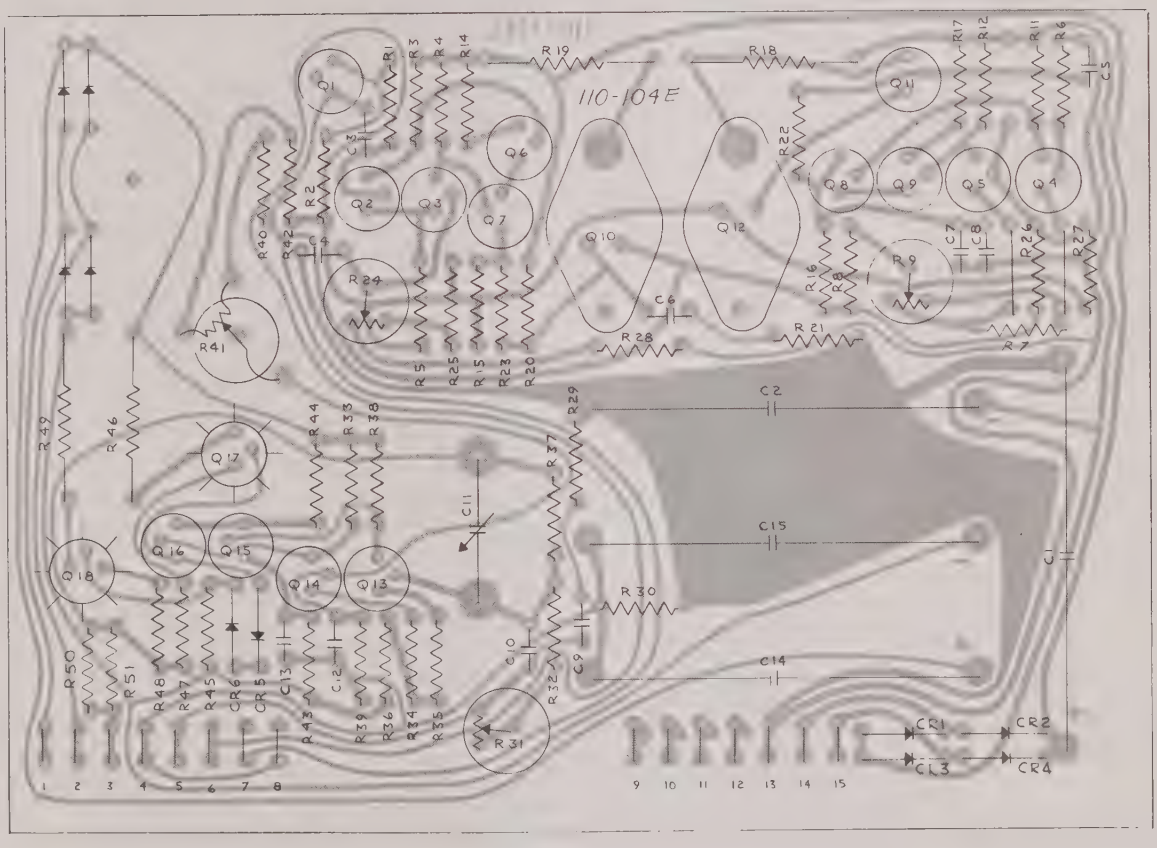


Figure 5-6. Power Supply and Output Amplifier Assembly.

CIRCUIT REFERENCE	PART NO.	DESCRIPTION	QTY PER ASSY	MANUFACTURER
C1, C2	34-750BP2000	CAPACITOR, Electrolytic, 15v 2000 mfd	2	Nashville
C3, C5, C6, C7, C8, C12	HY320	CAPACITOR, Ceramic, 12V 0.1 mfd	6	Sprague
C4	CCD102	CAPACITOR, Ceramic, 1000v 1000 mmf	1	Arco
C10	DD220	CAPACITOR, Ceramic, 1000v 22 mmf	1	CRL
C11	825FZ	CAPACITOR, Variohm, 3.0 to 12 mmf	1	CRL
C14, C15	34-750BP1000	CAPACITOR, Electrolytic, 25v 1000 mfd	2	Nashville
CR1, CR2, CR3, CR4, CR7, CR8, CR9, CR10	PS5666	DIODE	8	TRW
CR5, CR6	1N4009	DIODE	2	Gen Elect
Q15, Q16	2N3645	TRANSISTOR	2	Fairchild
Q1, Q4, Q5, Q7, Q9, Q11	2N3638	TRANSISTOR	6	Fairchild
Q2, Q3, Q6, Q8, Q13, Q14	2N3646	TRANSISTOR	6	Fairchild
Q10	40250	TRANSISTOR	1	RCA
Q12	2N3740	TRANSISTOR	1	Motorola
Q17	2N2959	TRANSISTOR	1	Motorola
Q18	2N3134	TRANSISTOR	1	Motorola
R1, R28, R34 R35	RN60D	RESISTOR, Metal Film, 1/4W 1% 100 ohm	4	Electra
R2	RN60D	RESISTOR, Metal Film, 1/4W 1% 2870 ohm	1	Electra
R3, R8, R12	RC20GF272K	RESISTOR, Carbon, 1/2W 10% 2700 ohm	3	Stackpole
R4, R11	RC20GF392K	RESISTOR, Carbon, 1/2W 10% 3900 ohm	2	Stackpole
R5, R15, R16	RC20GF222K	RESISTOR, Carbon, 1/2W 10% 2200 ohm	3	Stackpole
R6	RN60D	RESISTOR, Metal Film, 1/4W 1% 511Ω	1	Electra
R7	RC20GF560K	RESISTOR, Carbon, 1/2W 10% 56 ohm	1	Stackpole
R9, R24, R31	FR-251M	POTENTIOMETER, Single Turn, 250 ohm	3	Allen Bradley

Power Supply and Output Amplifier Assembly Parts List (Sheet 1 of 2).

CIRCUIT REFERENCE	PART NO.	DESCRIPTION	QTY PER ASSY	MANUFACTURER
R14, R17 R22, R23	RC20GF101K	RESISTOR, Carbon, 1/2W 10% 100 ohm	5	Stackpole
R18, R19	PW-10	RESISTOR, Wirewound, 5W 10% 10 ohm	2	Stackpole
R20	RC20GF472K	RESISTOR, Carbon, 1/2W 10% 4700 ohm	1	Stackpole
R21	RC20GF100K	RESISTOR, Carbon, 1/2W 10% 10 ohm	1	Stackpole
R25, R26,R27, R39	RN60D	RESISTOR, Metal Film, 1/4W 1% 1000 ohm	4	Electra
R29	RC20GF151K	RESISTOR, Carbon, 1/2W 10% 150 ohm	1	Stackpole
R30	RC20GF220K	RESISTOR, Carbon, 1/2W 10% 22 ohm	1	Stackpole
R32	RN60D	RESISTOR, Metal Film, 1/4W 1% 909 ohm	1	Electra
R33, R38	RN60D	RESISTOR, Metal Film, 1/4W 1% 3830 ohm	2	Electra
R36	RC20GF622J	RESISTOR, Carbon, 1/2W 5% 6200 ohm	1	Stackpole
R37	RN60D	RESISTOR, Metal Film, 1/4W 1% 6980 ohm	1	Electra
R40, R42	RN60D	RESISTOR, Metal Film, 1/4W 1% 10000 ohm	2	Electra
R43	RC20GF202J	RESISTOR, Carbon, 1/2W 5% 2000 ohm	1	Stackpole
R44	RC20GF221K	RESISTOR, Carbon, 1/2W 10% 220 ohm	1	Stackpole
R45	RC20GF182K	RESISTOR, Carbon, 1/2W 10% 1800 ohm	1	Stackpole
R46, R49	RC42GF910J	RESISTOR, Carbon, 2W 5% 91 ohm	2	Stackpole
R50, R51	RN60D	RESISTOR, Metal Film, 1/4W 1% 49.9 ohm	2	Electra
	013-5200	CONNECTOR PIN	14	Elco
	NF207	HEATSINK	2	Wakefield
	2010B-1	TERMINAL	11	USECO
R41	FR103M	POTENTIOMETER, Single Turn 10000 ohm	1	Allen Bradley

Power Supply and Output Amplifier Assembly Parts List (Sheet 2 of 2).

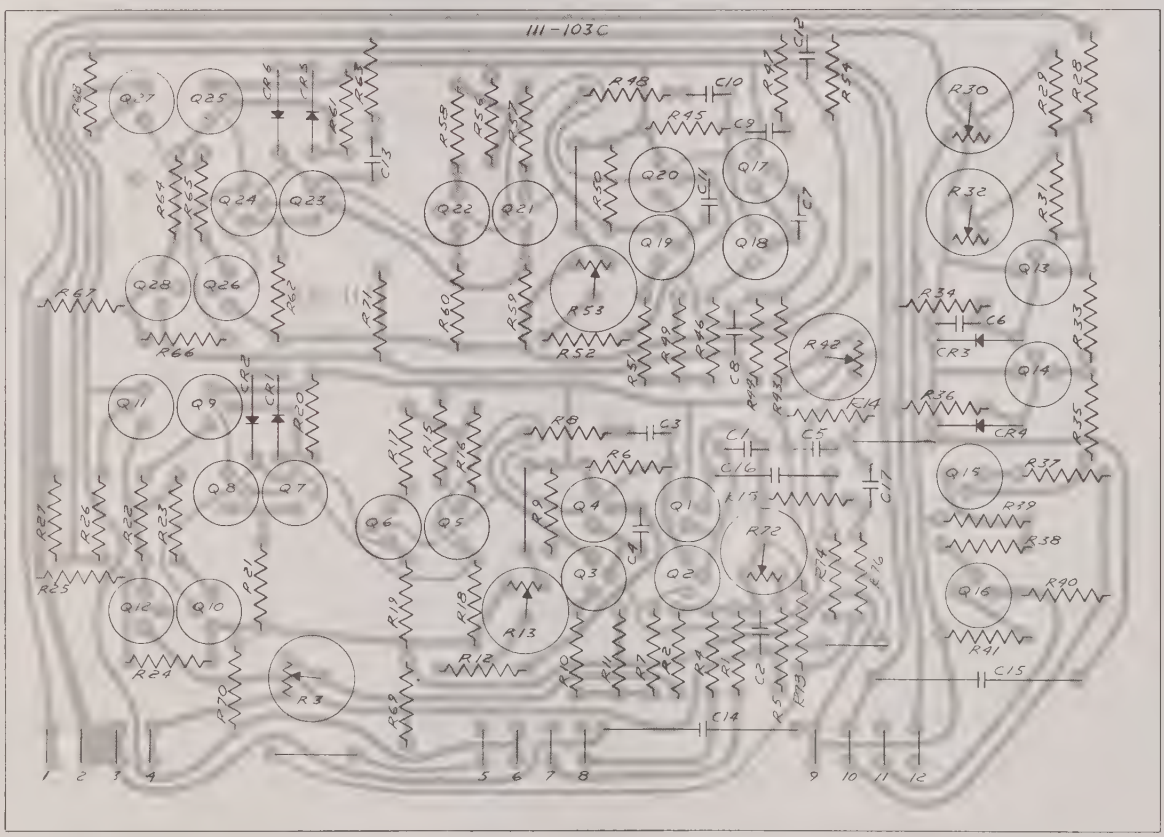


Figure 5-7. VCG Board Assembly.

CIRCUIT REFERENCE	PART NO.	DESCRIPTION	QTY PER ASSY	MANUFACTURER
C1, C4, C6, C7, C8, C11	DD101	CAPACITOR, Ceramic, 1000v 100 mmf	6	CRL
C2	DD300	CAPACITOR, Ceramic, 1000v 30 mmf	1	CRL
C3, C9, C10	DD471	CAPACITOR, Ceramic, 1000v 470 mmf	3	CRL
C5, C12, C17	CK103	CAPACITOR, Ceramic, 50v 0.01 mfd	3	CRL
C13	DD221	CAPACITOR, Ceramic, 1000v 220 mmf	1	CRL
C14, C15	TL1135	CAPACITOR, Electrolytic, 12v 100 mfd	2	Sprague
CR1, CR2, CR3, CR4, CR5, CR6	1N4009	DIODE	6	Gen Elect
Q1, Q2, Q3, Q4, Q7, Q8, Q9, Q15, Q17, Q18, Q19, Q20 Q23, Q24, Q25	2N3646	TRANSISTOR	15	Fairchild
Q5, Q6, Q10, Q11, Q12, Q13, Q14, Q15, Q16 Q21, Q22, Q26	2N3640	TRANSISTOR	12	Fairchild
Q27, Q28	2N3903	TRANSISTOR	2	Motorola
R1	RN60D	RESISTOR, Metal Film, 1/4W 1% 95300 ohm	1	Electra
R3, R13, R53	FR103M	POTENTIOMETER, Single Turn, 10000 ohm	3	Allen Bradley
R4	RN60D	RESISTOR, Metal Film, 1/4W 1% 12100 ohm	1	Electra
R5	RN60D	RESISTOR, Metal Film, 1/4W 1% 6340 ohm	1	Electra
R6, R9, R45, R50	RN60D	RESISTOR, Metal Film, 1/4W 1% 23700 ohm	4	Electra

VCG Board Assembly Parts List (Sheet 1 of 3).

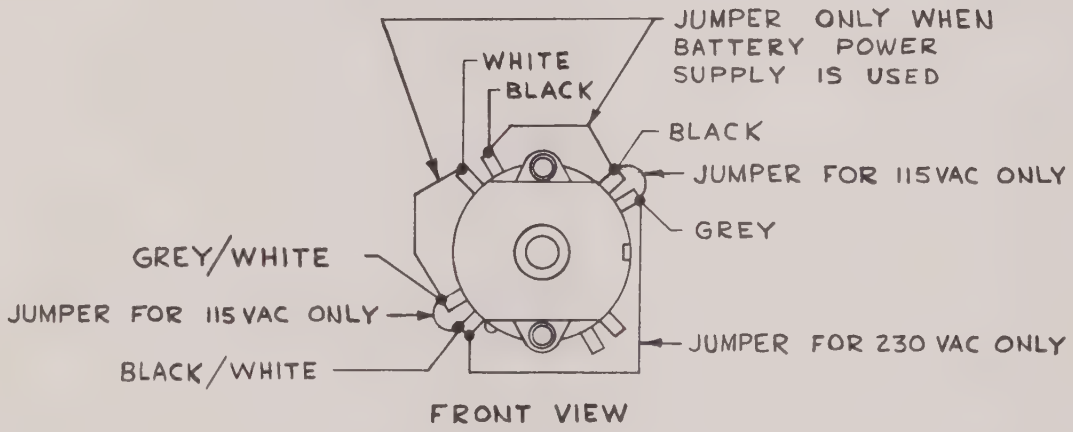
CIRCUIT REFERENCE	PART NO.	DESCRIPTION	QTY PER ASSY	MANUFACTURER
R7, R10, R28, R46, R51	RN60D	RESISTOR, Metal Film, 1/4W 1% 1000 ohm	5	Electra
R11, R15, R49, R56	RN60D	RESISTOR, Metal Film, 1/4W 1% 10000 ohm	4	Electra
R2, R18, R19, R59 R60	RN60D	RESISTOR, Metal Film, 1/4W 1% 7500 ohm	5	Electra
R30, R32, R42, R72	FR251M	POTENTIOMETER, Single Turn, 250 ohm	4	Allen Bradley
R16, R17, R57, R58	RN60D	RESISTOR, Metal Film, 1/4W 1% 100 ohm	4	Electra
R20, R61	RN60D	RESISTOR, Metal Film, 1/4W 1% 2000 ohm	2	Electra
R21, R62	RC20GF221K	RESISTOR, Carbon, 1/2W 10% 220 ohm	2	Stackpole
R22, R23, R64, R65	RC20GF150K	RESISTOR, Carbon, 1/2W 10% 15 ohm	4	Stackpole
R25, R67	RC20GF123K	RESISTOR, Carbon, 1/2W 10% 12000 ohm	2	Stackpole
R26, R68	RC20GF202J	RESISTOR, Carbon, 1/2W 5% 2000 ohm	2	Stackpole
R27, R39,	RC20GF152K	RESISTOR, Carbon, 1/2W 10% 1500 ohm	2	Stackpole
R29	RN60D	RESISTOR, Metal Film, 1/4W 1% 1780 ohm	1	Electra
R31	RN60D	RESISTOR, Metal Film, 1/4W 1% 2370 ohm	1	Electra
R33	RC20GF182K	RESISTOR, Carbon, 1/2W 10% 1800 ohm	1	Stackpole
R34, R36	RC20GF472K	RESISTOR, Carbon, 1/2W 10% 4700 ohm	2	Stackpole
R35, R38	RC20GF101K	RESISTOR, Carbon, 1/2W 10% 100 ohm	2	Stackpole
R37, R41	RC20GF470K	RESISTOR, Carbon, 1/2W 10% 47 ohm	2	Stackpole
R40	RC20GF622J	RESISTOR, Carbon, 1/2W 5% 6200 ohm	1	Stackpole

VCG Board Assembly Parts List (Sheet 2 of 3).

CIRCUIT REFERENCE	PART NO.	DESCRIPTION	QTY PER ASSY	MANUFACTURER
R43	RN60D	RESISTOR, Metal Film, 1/4W 1% 2870 ohm	1	Electra
R44, R55	RN60D	RESISTOR, Metal Film, 1/4W 1% 3010 ohm	2	Electra
R47, R48, R63	RC20GF151K	RESISTOR, Carbon, 1/2W 10%, 150 ohm	3	Stackpole
R69, R70, R71	RC20GF224K	RESISTOR, Carbon, 1/2W 10% 220000 ohm	3	Stackpole
	05-3303	SOCKET, TRANSISTOR	9	Elco
	013-5200	CONNECTOR, PIN	14	Elco
R12, R52	RN60D	RESISTOR, Metal Film, 1/4W 1% 698000 ohm	2	Electra
R14	RN60D	RESISTOR, Metal Film, 1/4W 1% 3830 ohm	1	Electra
R52	RN60D	RESISTOR, Metal Film, 1/4W 1% 178000 ohm	1	Electra
R54	RN60D	RESISTOR, Metal Film, 1/4W 1% 1470 ohm	1	Electra
R73	RN60D	RESISTOR, Metal Film, 1/4W 1% 4640 ohm	1	Electra
R74	RC20GF561K	RESISTOR, Carbon, 1/2W 10% 560 ohm	1	Stackpole
R75, R76	RC20GF242K	RESISTOR, Carbon, 1/2W 10% 2400 ohm	2	Stackpole

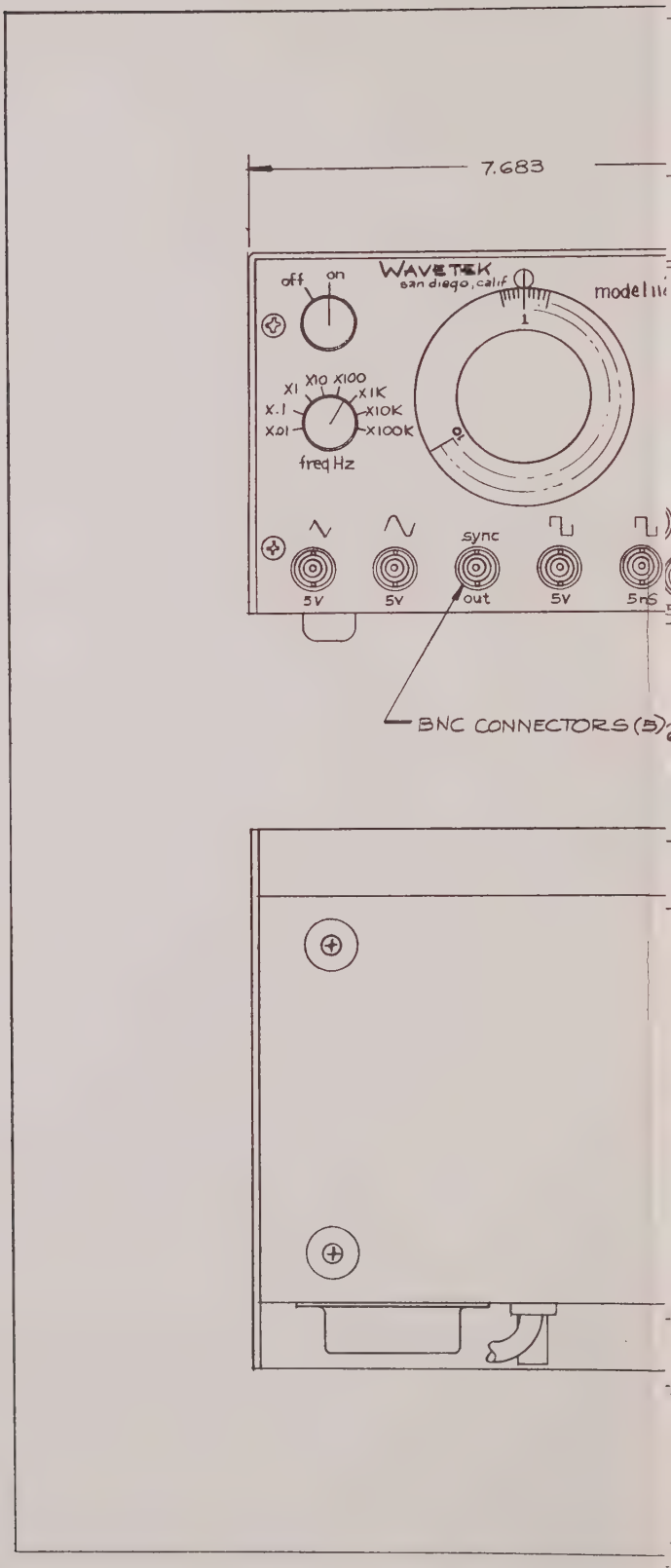
VCG Board Assembly Parts List (Sheet 3 of 3).

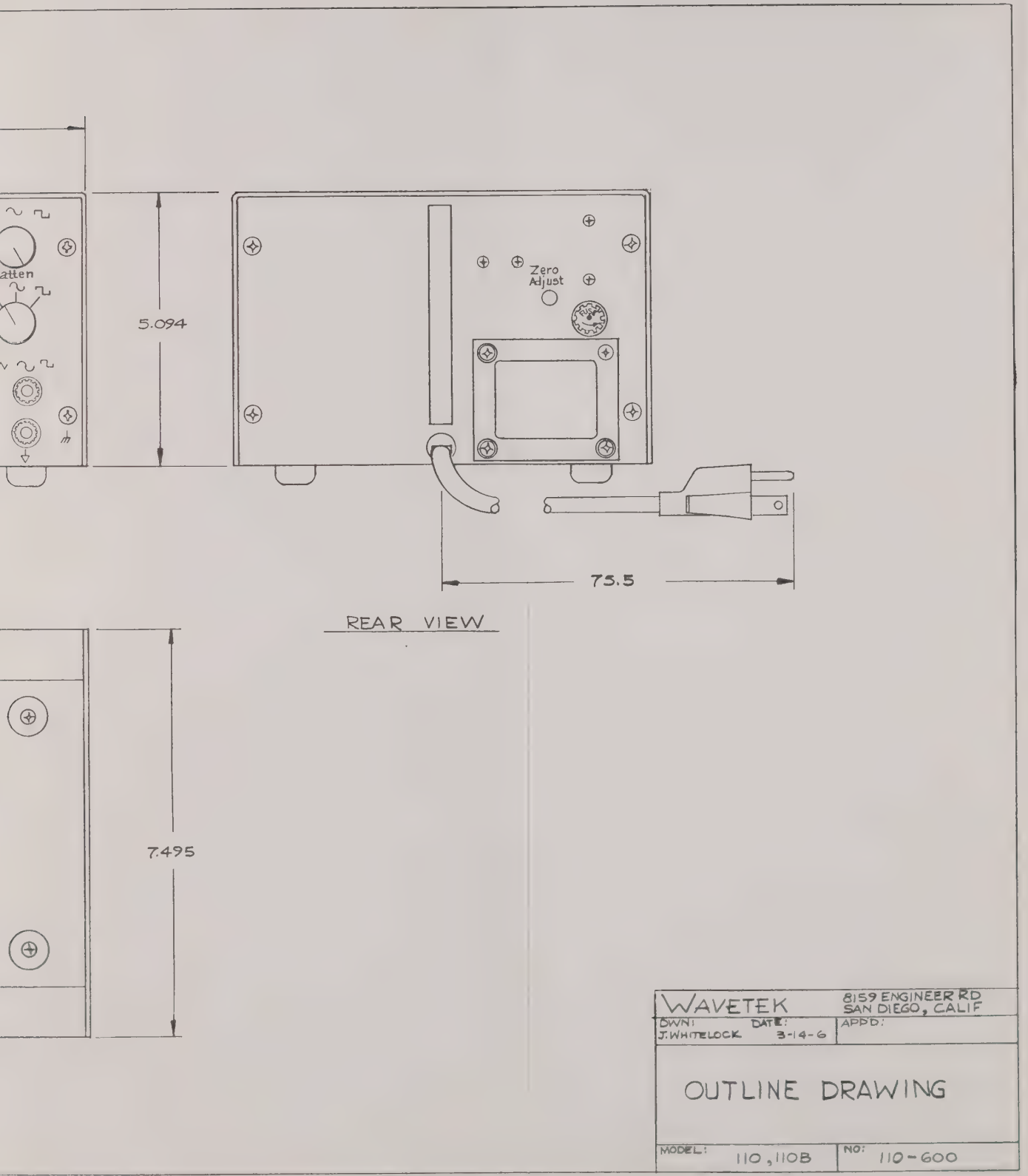
SECTION VI
SCHEMATIC DIAGRAMS



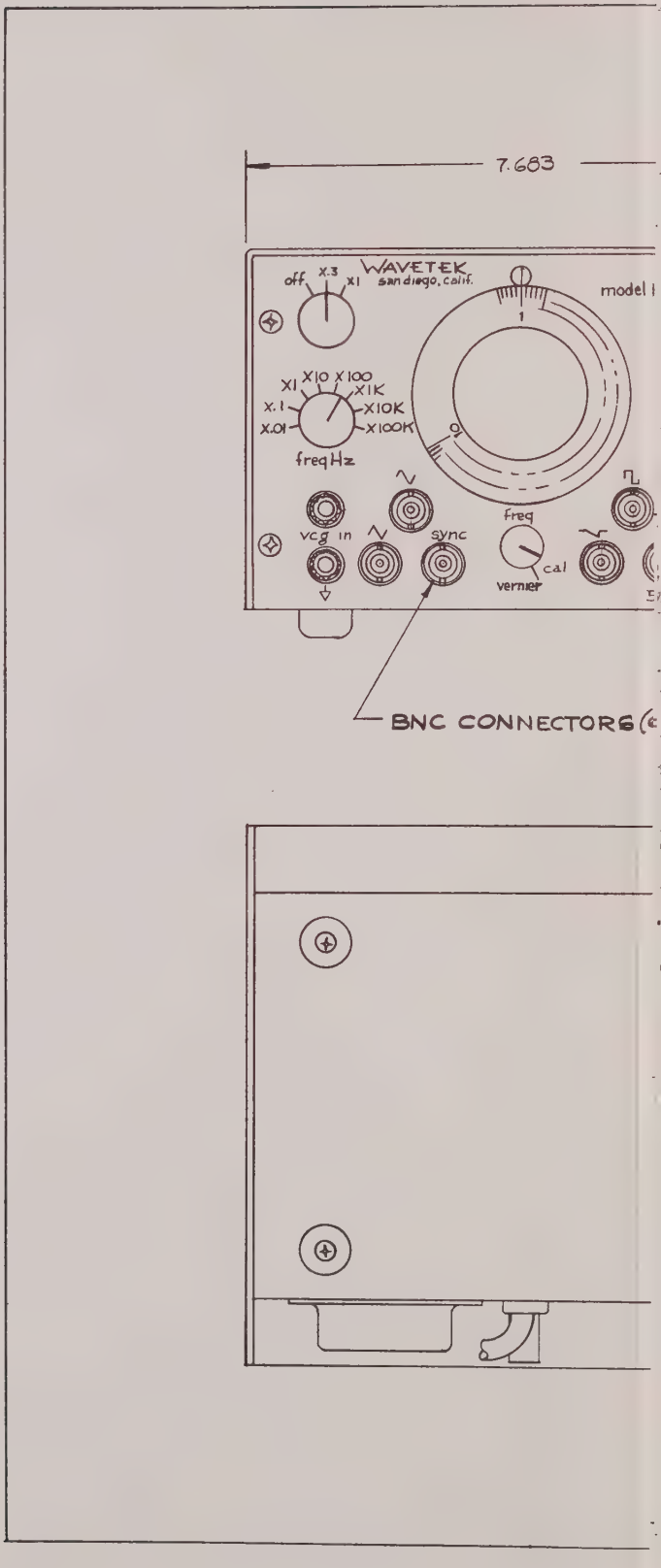
115/230 V SWITCH WIRING

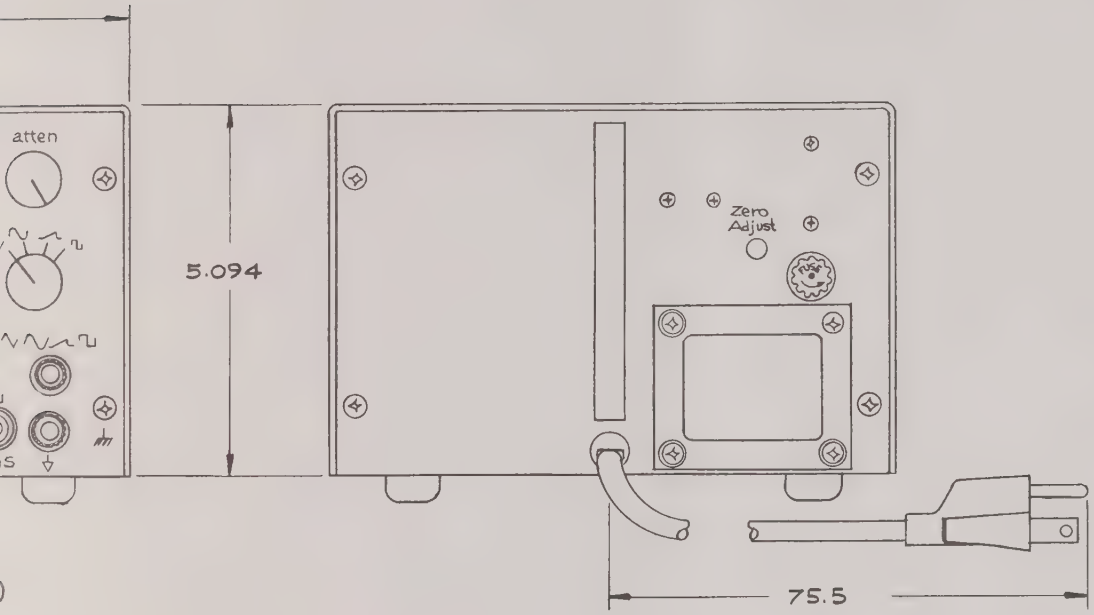
115/230 VAC Switch Wiring Schematic Diagram


7.683
WAVETEK
san diego, calif
model
off
on
1
0
X1
X10
X100
X1K
X10K
X100K
X.1
X.01
freq Hz
sync
5V
5V
out
5V
5nS
BNC CONNECTORS (5)

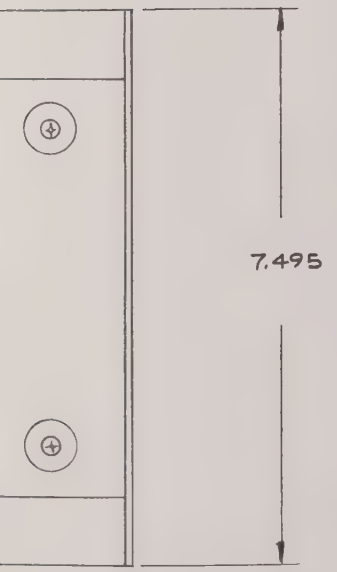


Outline Drawing (Model 110)


7.683
WAVETEK
san diego, calif.
model
off
X.3
X1
X1
X10
X100
X1K
X10K
X100K
X.1
X.01
freq Hz
1
0
freq
cal
vernier
vcg in
sync
BNC CONNECTORS

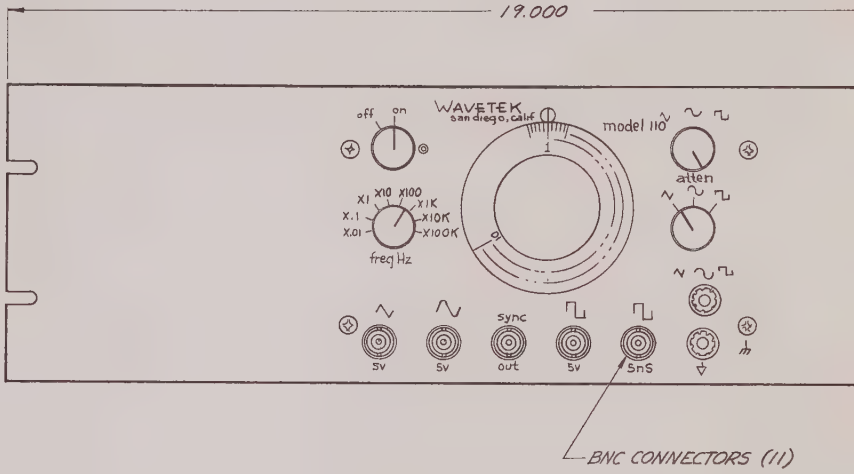


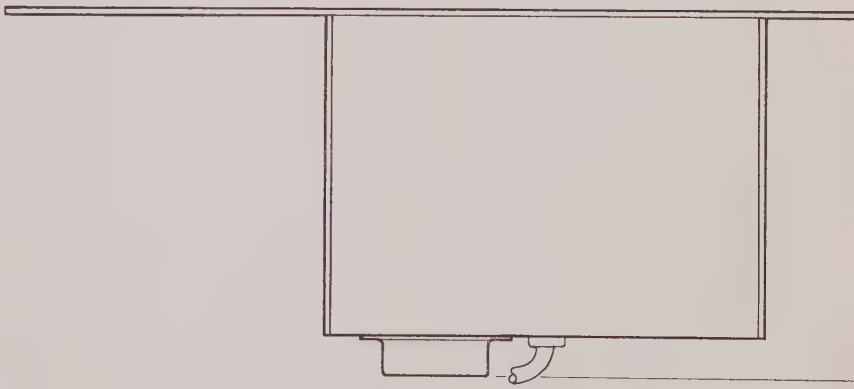
REAR VIEW

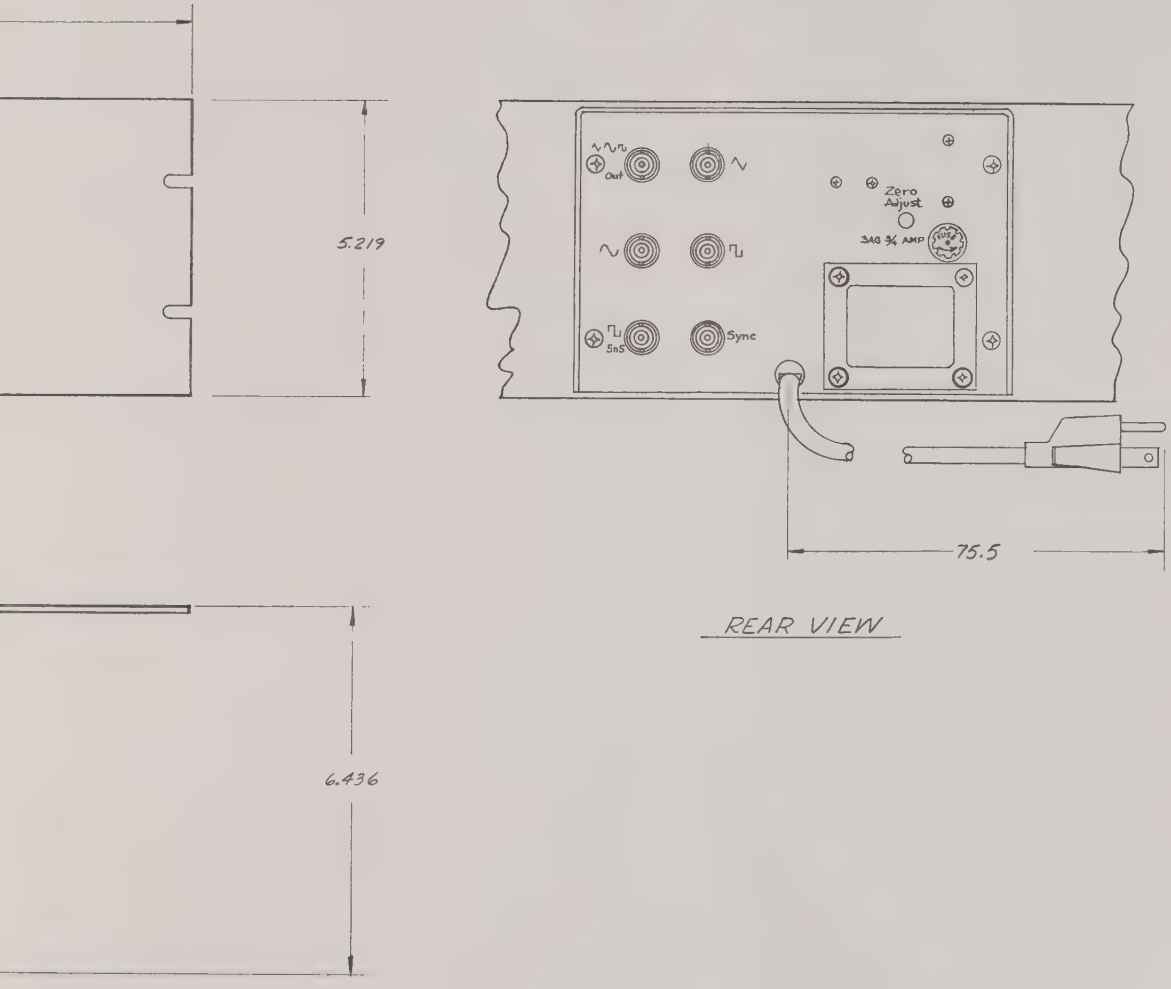


WAVETEK		8159 ENGINEER RD SAN DIEGO, CALIF.
DWN: J.WHITELOCK	DATE: 3-14-6	APP'D:
OUTLINE DRAWING		
MODEL: 111, 111B		NO: 111-600

Outline Drawing (Model 111)


19.000
off
on
WAVETEK
san diego, calif
model 110
atten
X1
X10
X100
X1K
X10K
X100K
X.1
X.01
freq Hz
sync
5v
5v
out
5v
5nS
BNC CONNECTORS (11)

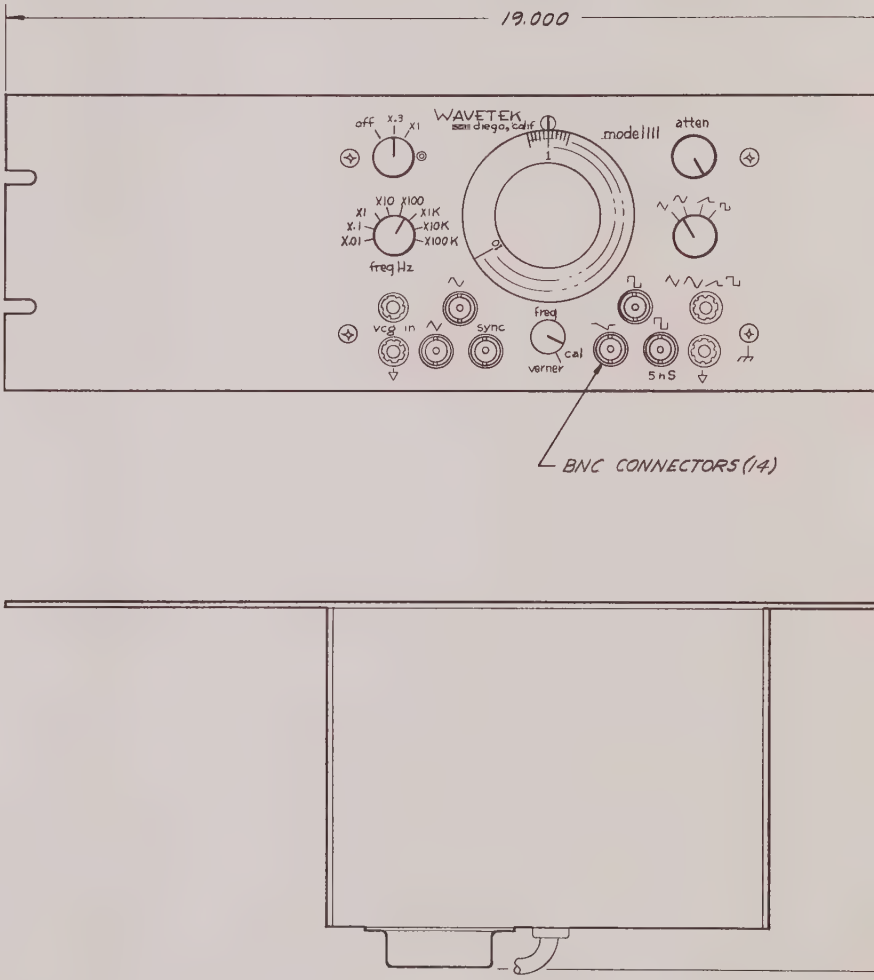


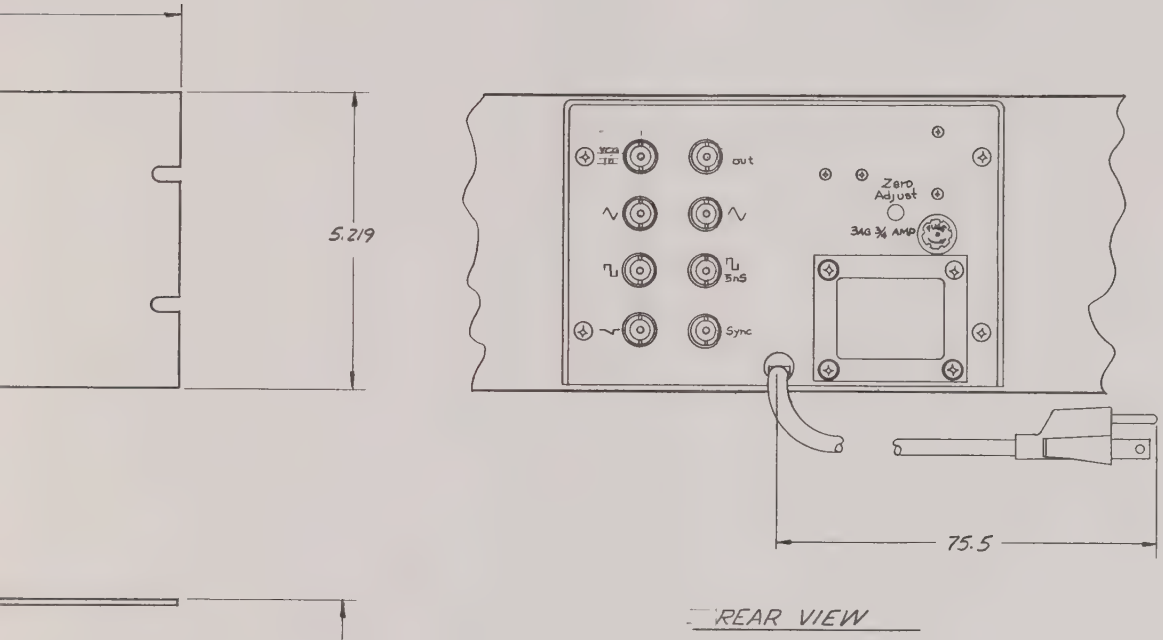


REAR VIEW

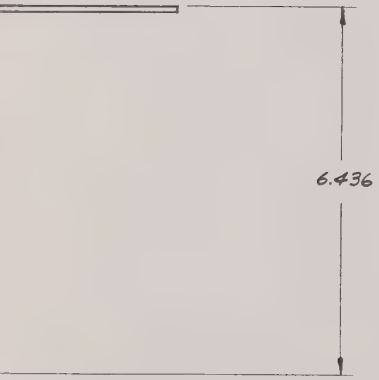
WAVETEK	8139 ENGINEER RD SAN DIEGO, CALIF
DWN MONTELOCK DATE 7-14-6	APP'D.
OUTLINE DWG. - RACK MOUNT	
MODEL 110, 110B	NO 110-601

Outline Drawing (Model 110 Rack Mount)


19.000
WAVETEK
San diego, Calif
off
x.3
x1
mode
atten
X1
X.1
X.01
X10
X100
X1K
X10K
X100K
freq Hz
vcg in
sync
freq
cal
verner
5 nS
BNC CONNECTORS (14)

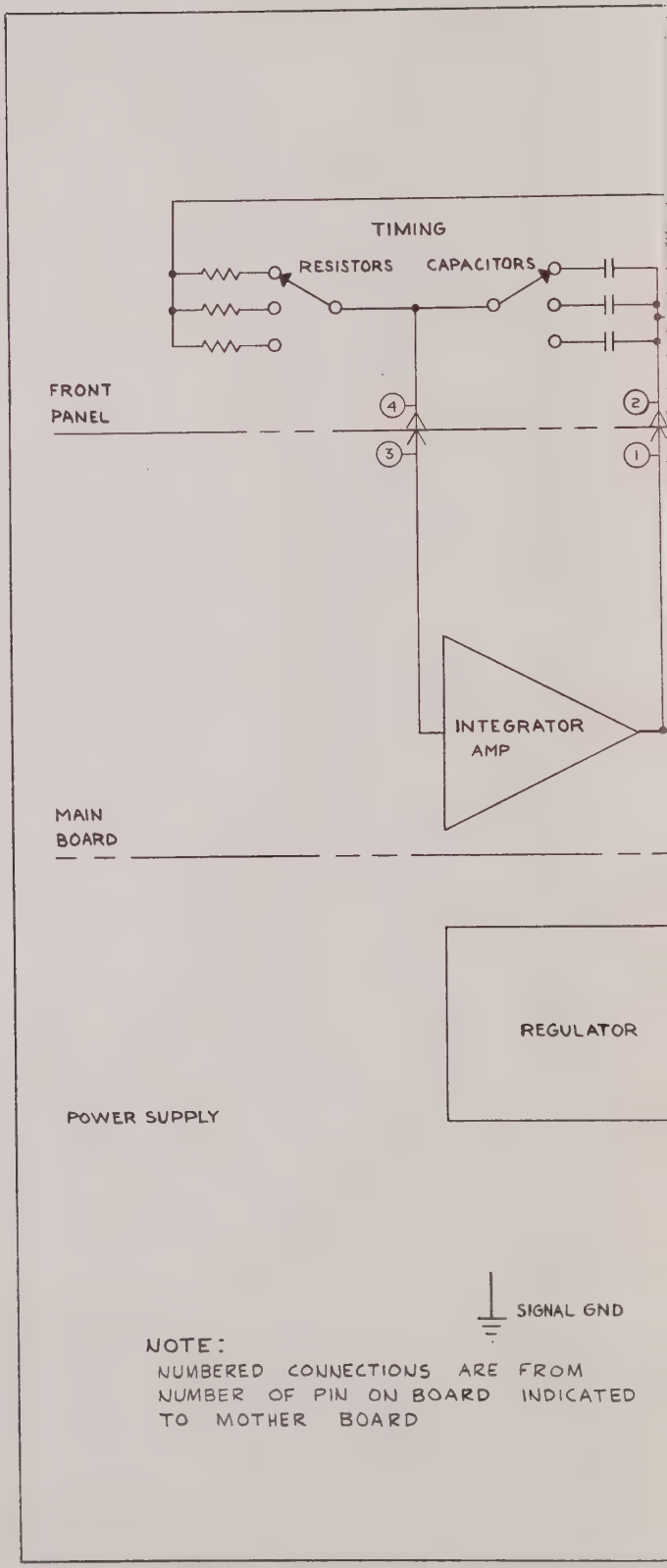


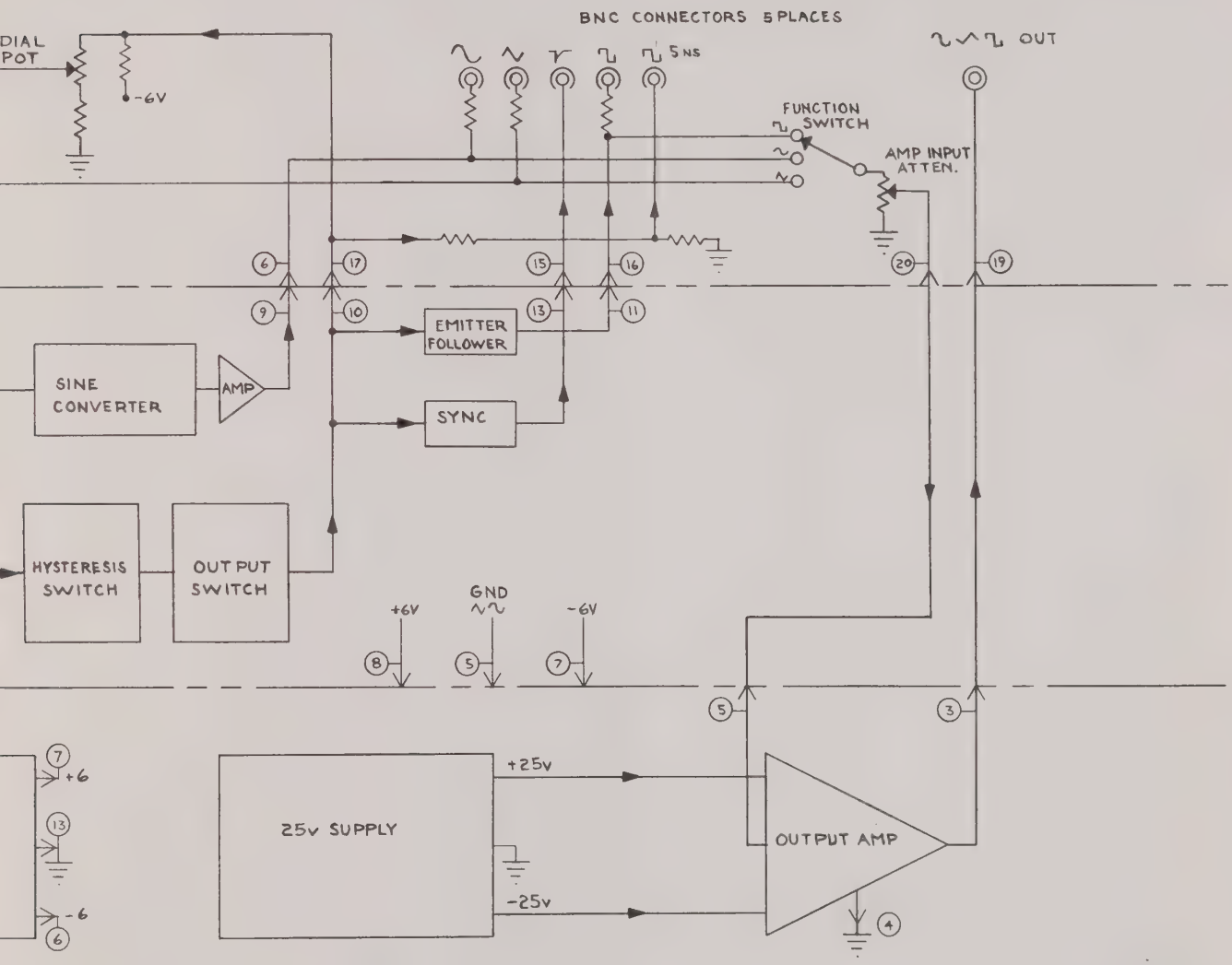
REAR VIEW



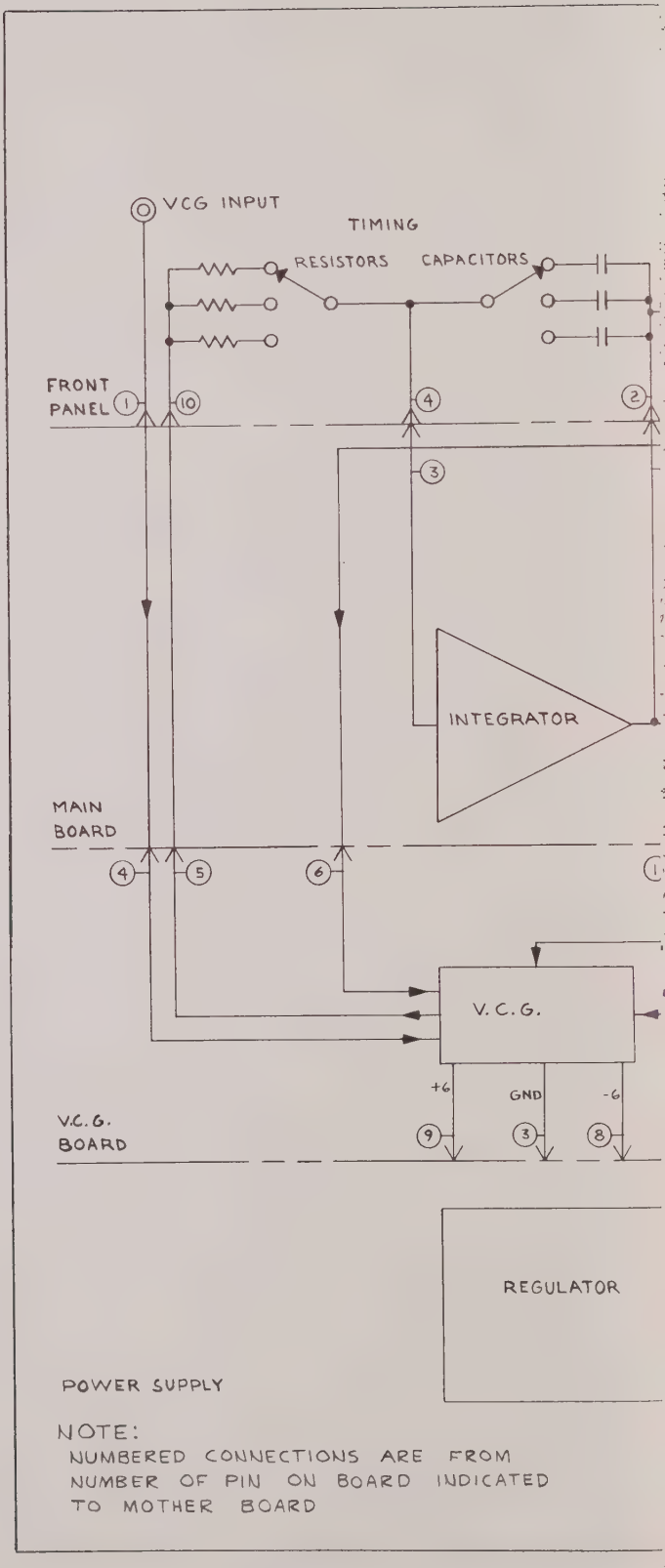
WAVETEK	8159 ENGINEER RD SAN DIEGO, CALIF
DWN: WHITELOCK DATE: 4-14-6	APPD:
OUTLINE DWG.- RACK MOUNT	
MODEL: 111, 111B	NO: 111-601

Outline Drawing (Model 111 Rack Mount)

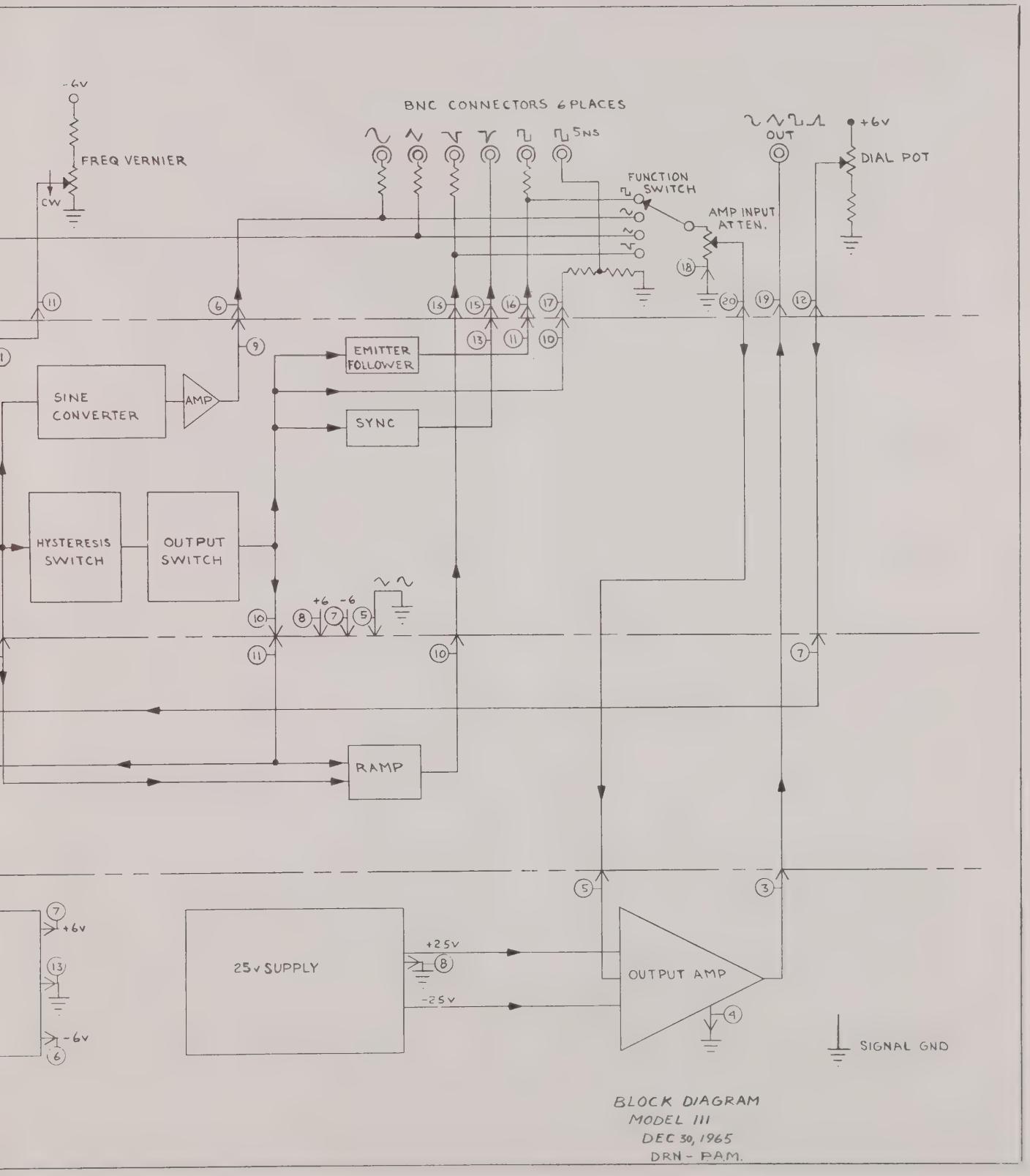

TIMING
RESISTORS
CAPACITORS
FRONT
PANEL
4
3
2
1
INTEGRATOR
AMP
MAIN
BOARD
REGULATOR
POWER SUPPLY
SIGNAL GND
NOTE:
NUMBERED CONNECTIONS ARE FROM
NUMBER OF PIN ON BOARD INDICATED
TO MOTHER BOARD



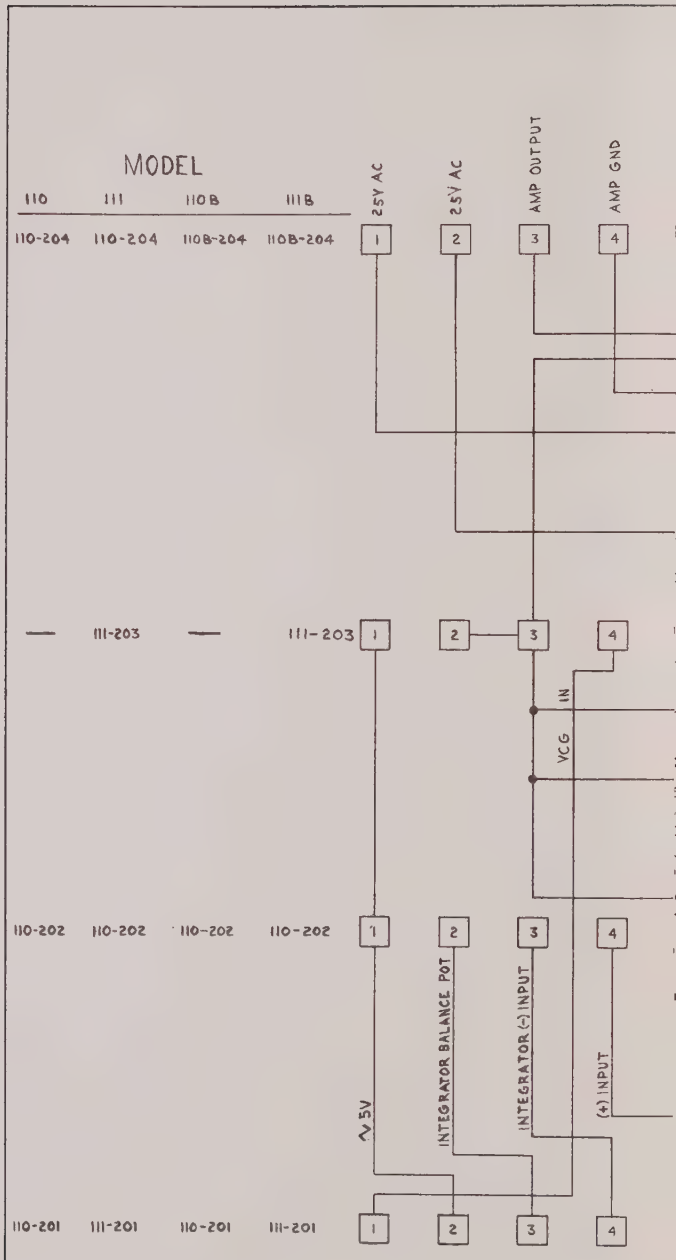
Model 110 Block Diagram



NOTE:
NUMBERED CONNECTIONS ARE FROM NUMBER OF PIN ON BOARD INDICATED TO MOTHER BOARD

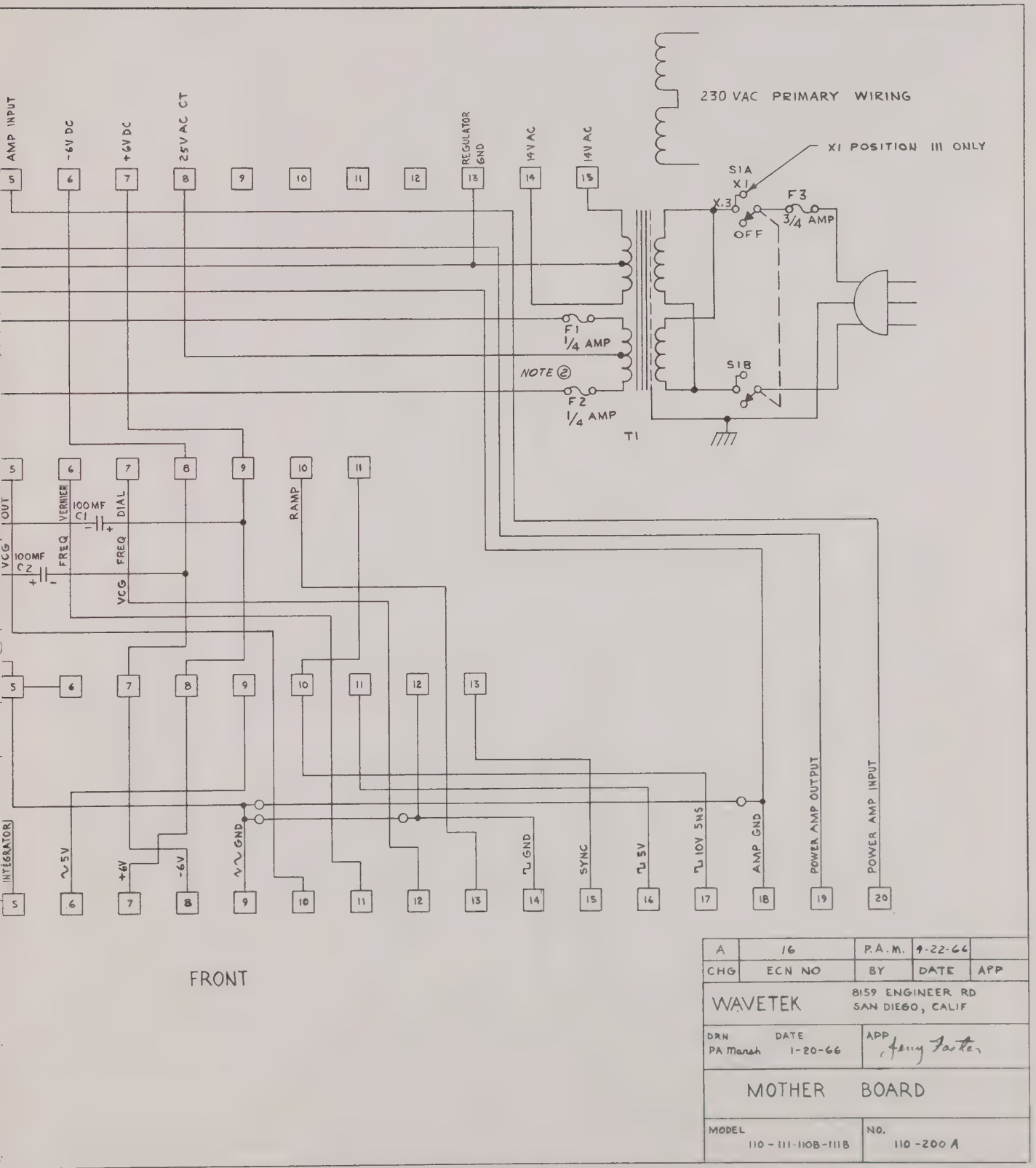


Model 111 Block Diagram



NOTE

1. PINS ARE NUMBERED FROM LEFT TO RIGHT AS VIEWED FROM COMPONENT SIDE OF CIRCUIT BOARD.
2. FOR "B" MODELS, USE ½ AMP 3AG FAST BLOW FOR F1 AND F2.



A	16	P.A.M.	9-22-66	
CHG	ECN NO	BY	DATE	APP

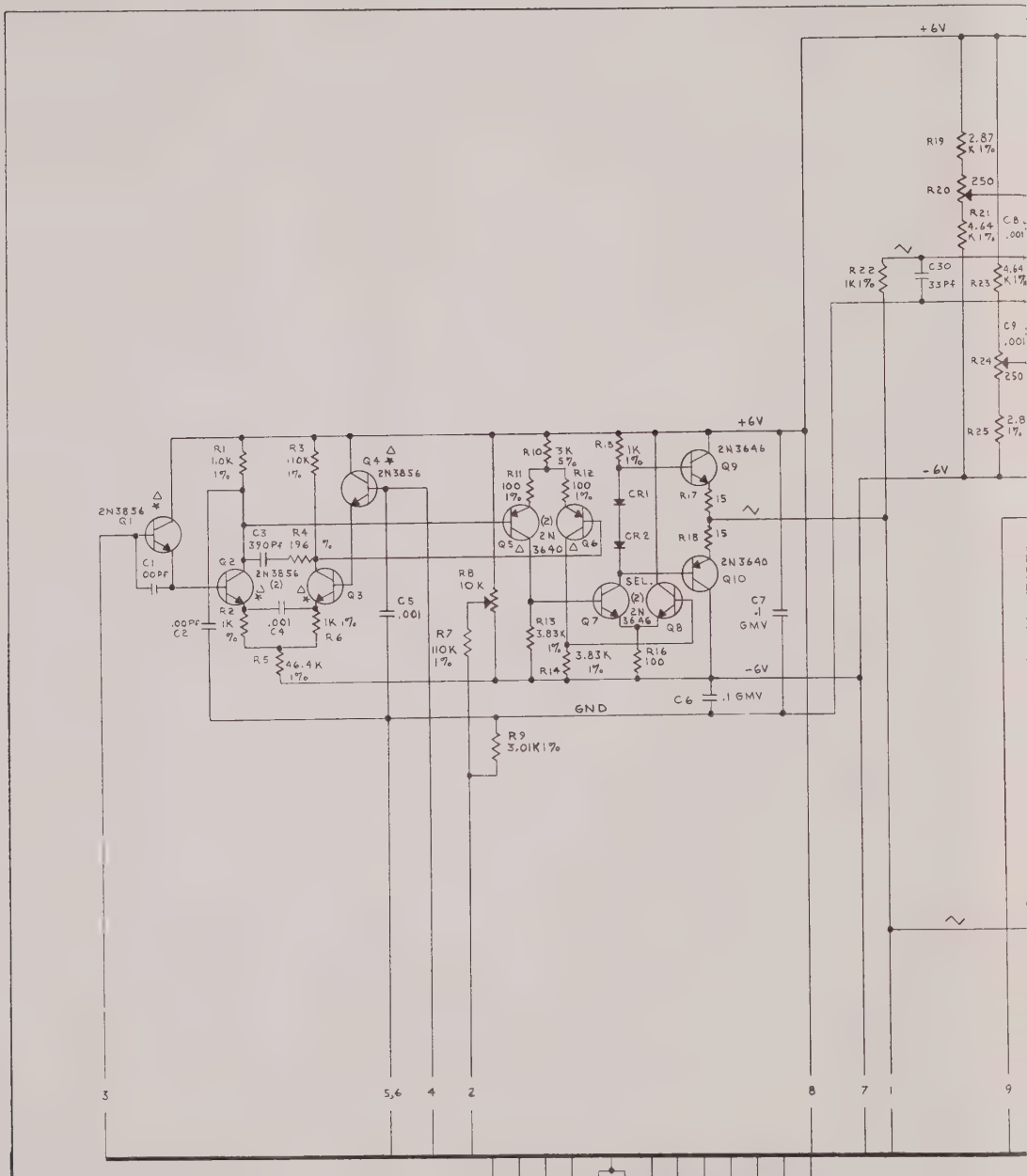
WAVETEK 8159 ENGINEER RD SAN DIEGO, CALIF

DRN P.A. Marsh DATE 1-20-66 APP Henry Foster

MOTHER BOARD

MODEL 110-111-110B-111B NO. 110-200A

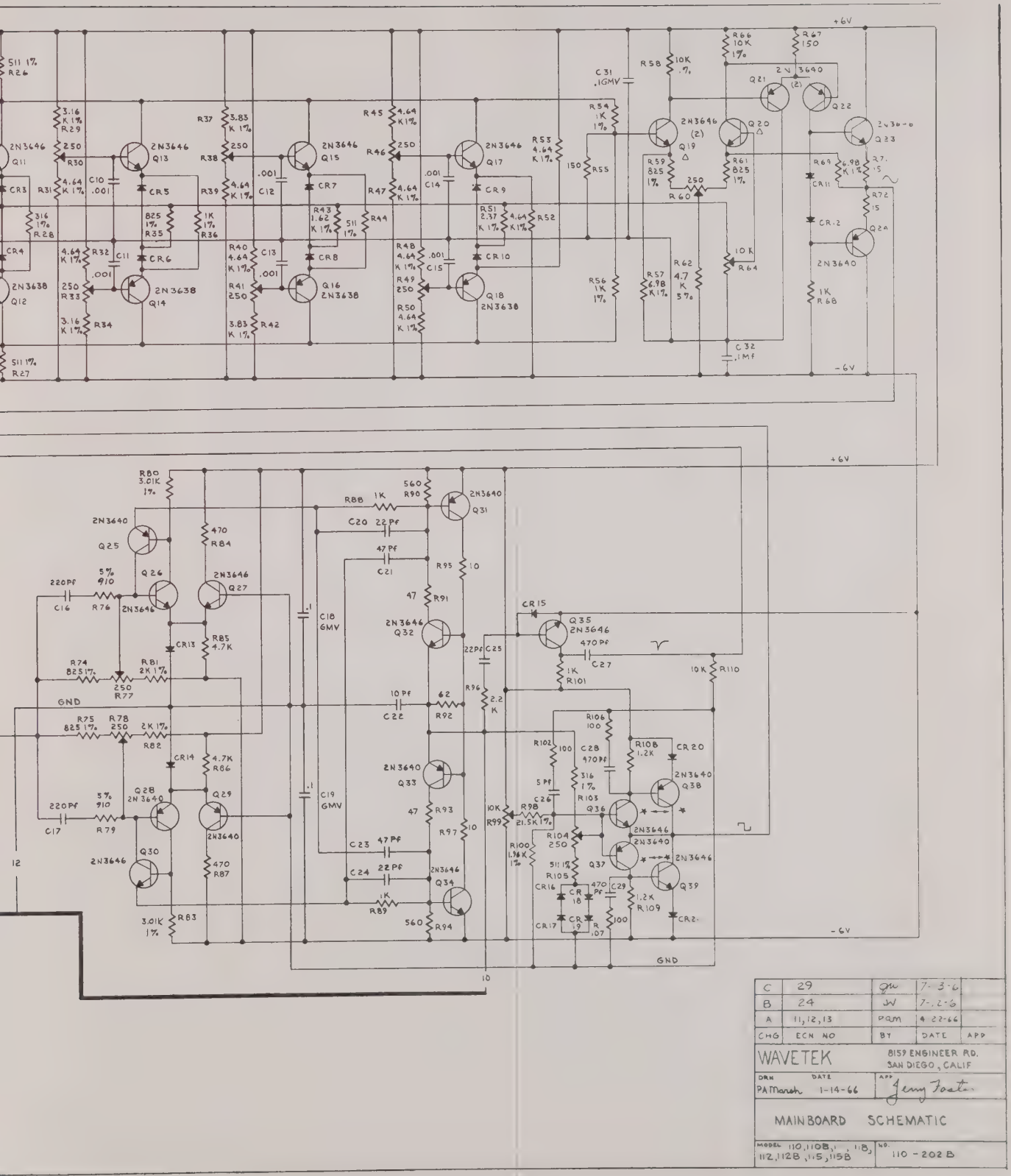
Model 110 and 111 Mother Board Schematic Diagram



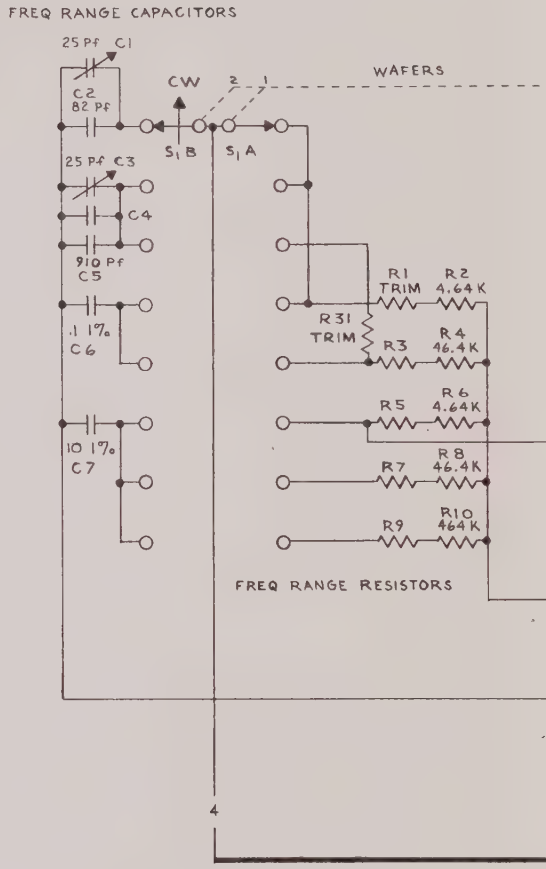
NOTE

UNLESS OTHERWISE SPECIFIED:

1. RESISTANCE IN OHMS, ±10%
2. CAPACITANCE IN MICROFARADS, ±10%
3. DIODES ARE 1N4009
4. PINS ARE NUMBERED FROM LEFT TO RIGHT AS VIEWED FROM COMPONENT SIDE OF CIRCUIT BOARD
5. * MATCHED PAIR – MATCHED FOR h_{FE} AND V_{BE}
6. ALL DIFFERENTIAL PAIRS MATCHED FOR 10% h_{FE} MATCH
7. S'YY; GUARANTEED MINIMUM VALUE
8. Δ INDICATES THERMALLY CONNECTED PAIRS
9. FAIRCHILD 2N3565 IS A LIMITED ALTERNATE FOR Q1, Q2, Q3, AND Q4



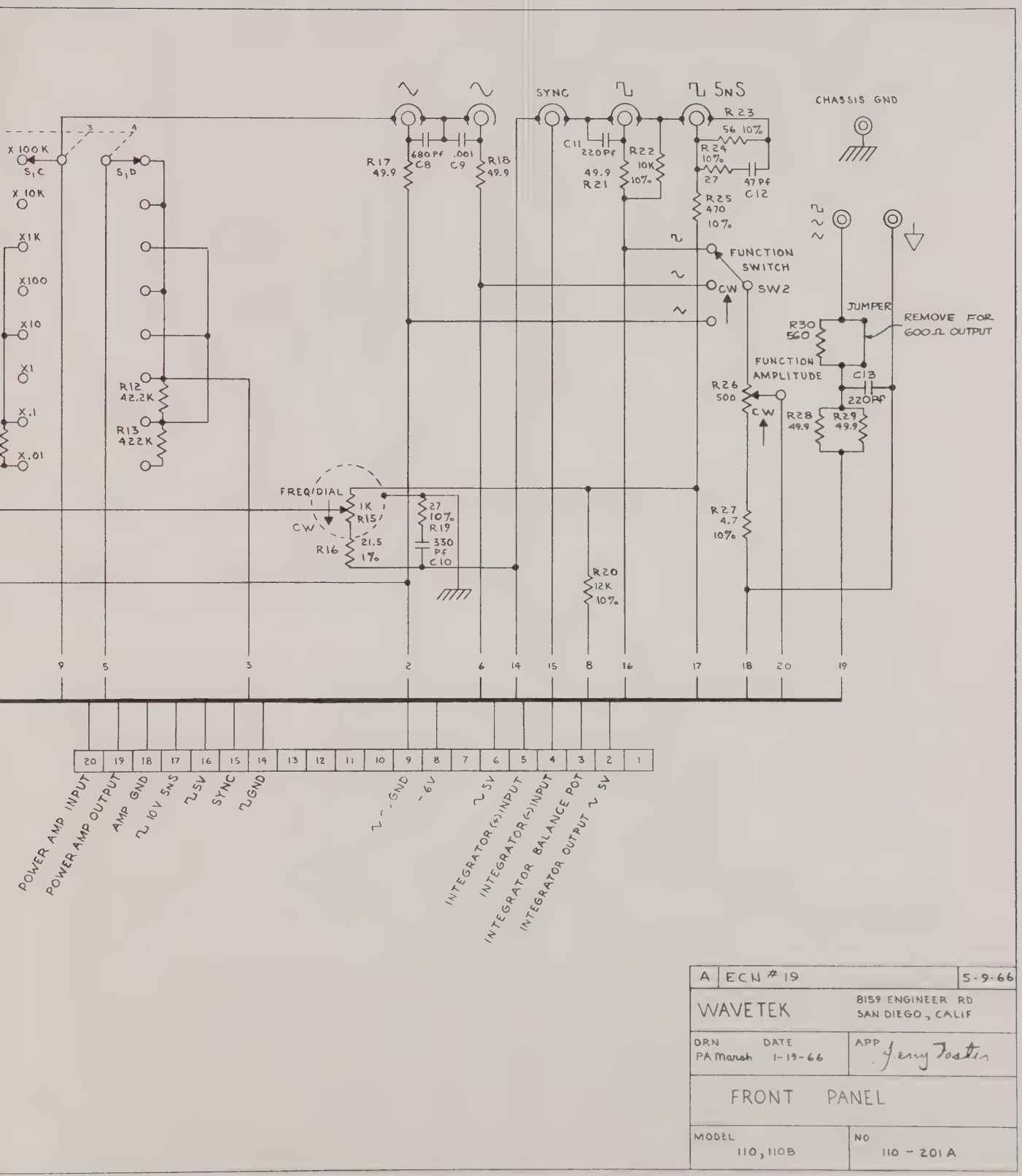
Model 110 and 111 Main Board Schematic Diagram



NOTE

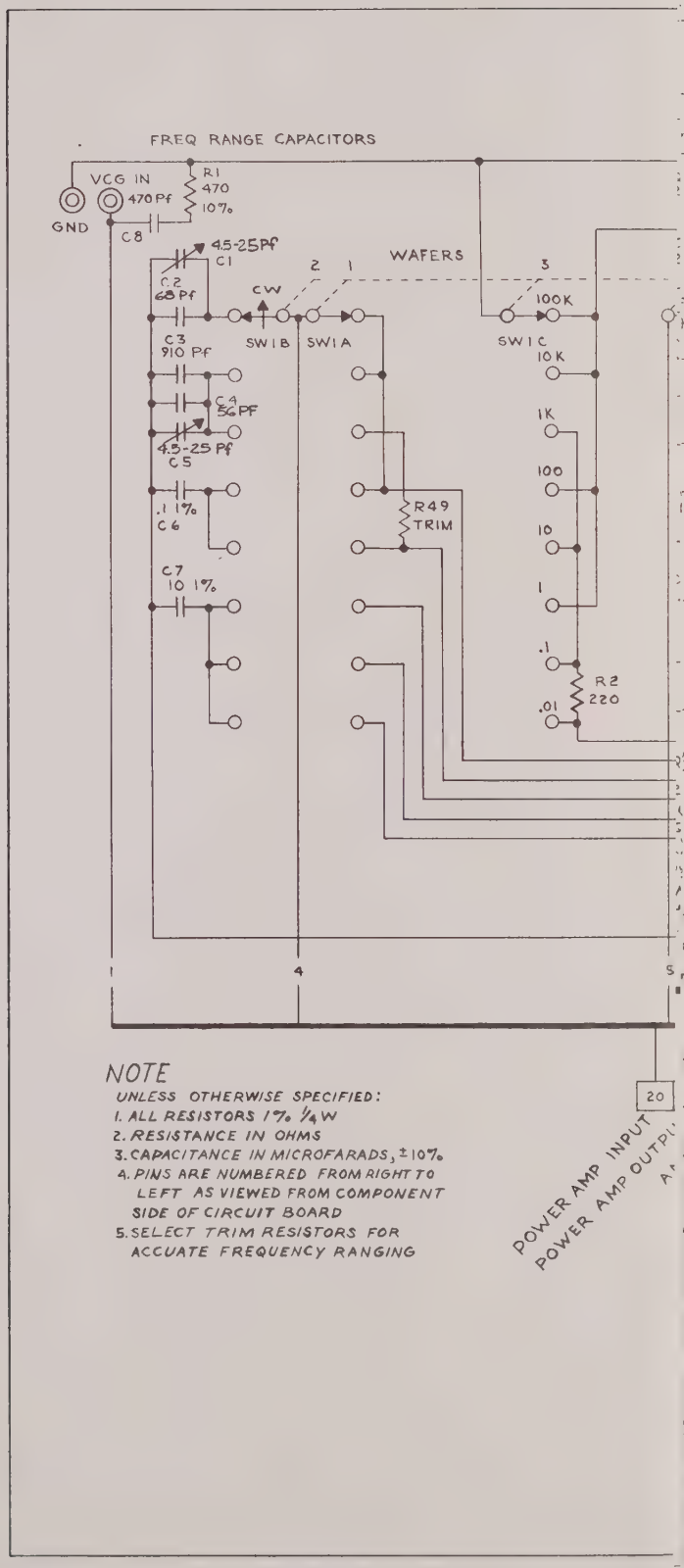
UNLESS OTHERWISE SPECIFIED:

1. ALL RESISTORS 1% ¼W
2. RESISTANCE IN OHMS
3. CAPACITANCE IN MICROFARADS, ± 10%
4. PINS ARE NUMBERED FROM RIGHT TO LEFT AS VIEWED FROM COMPONENT SIDE OF CIRCUIT BOARD
5. LABLED PINS ONLY, ACTUALLY APPEAR ON CIRCUIT BOARD



A	ECN # 19	5-9-66
WAVETEK		8159 ENGINEER RD SAN DIEGO, CALIF
DRN PA Marsh	DATE 1-19-66	APP Jerry Foster
FRONT PANEL		
MODEL 110, 110B		NO 110 - 201 A

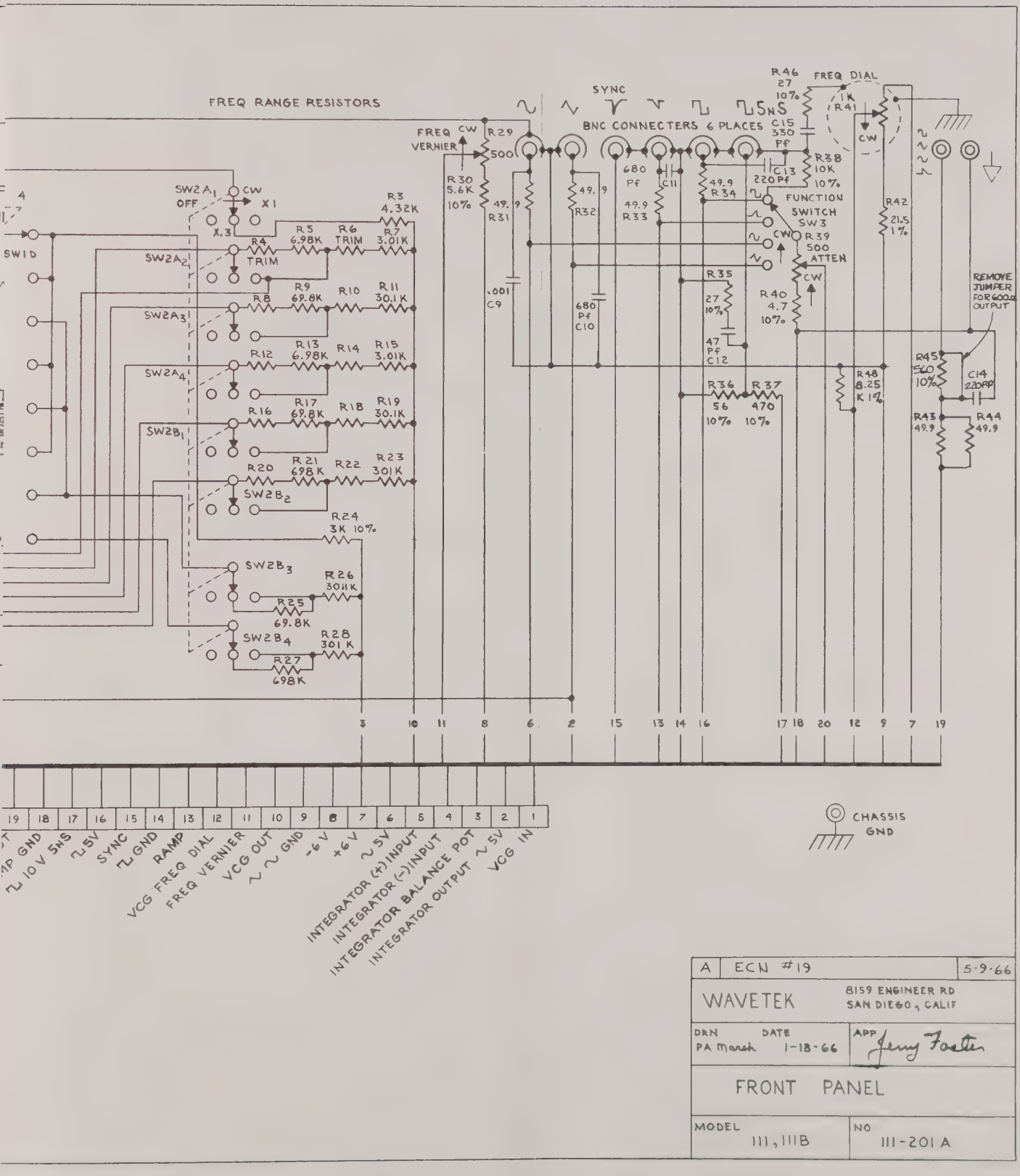
Front Panel Schematic Diagram (Model 110)



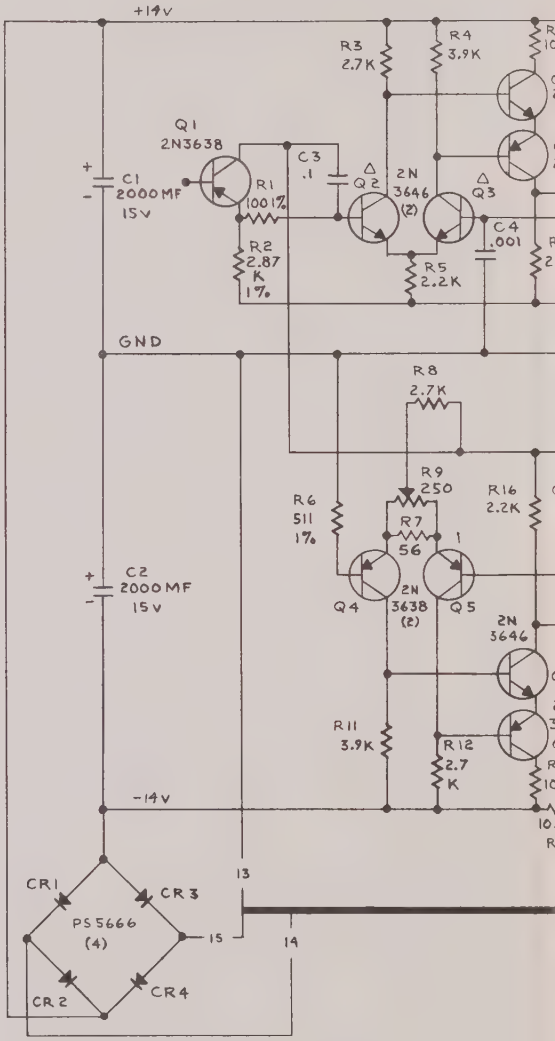
NOTE

UNLESS OTHERWISE SPECIFIED:

1. ALL RESISTORS 1% 1/4 W
2. RESISTANCE IN OHMS
3. CAPACITANCE IN MICROFARADS, ±10%
4. PINS ARE NUMBERED FROM RIGHT TO LEFT AS VIEWED FROM COMPONENT SIDE OF CIRCUIT BOARD
5. SELECT TRIM RESISTORS FOR ACCUATE FREQUENCY RANGING



Front Panel Schematic Diagram (Model 111)



LEGEND :

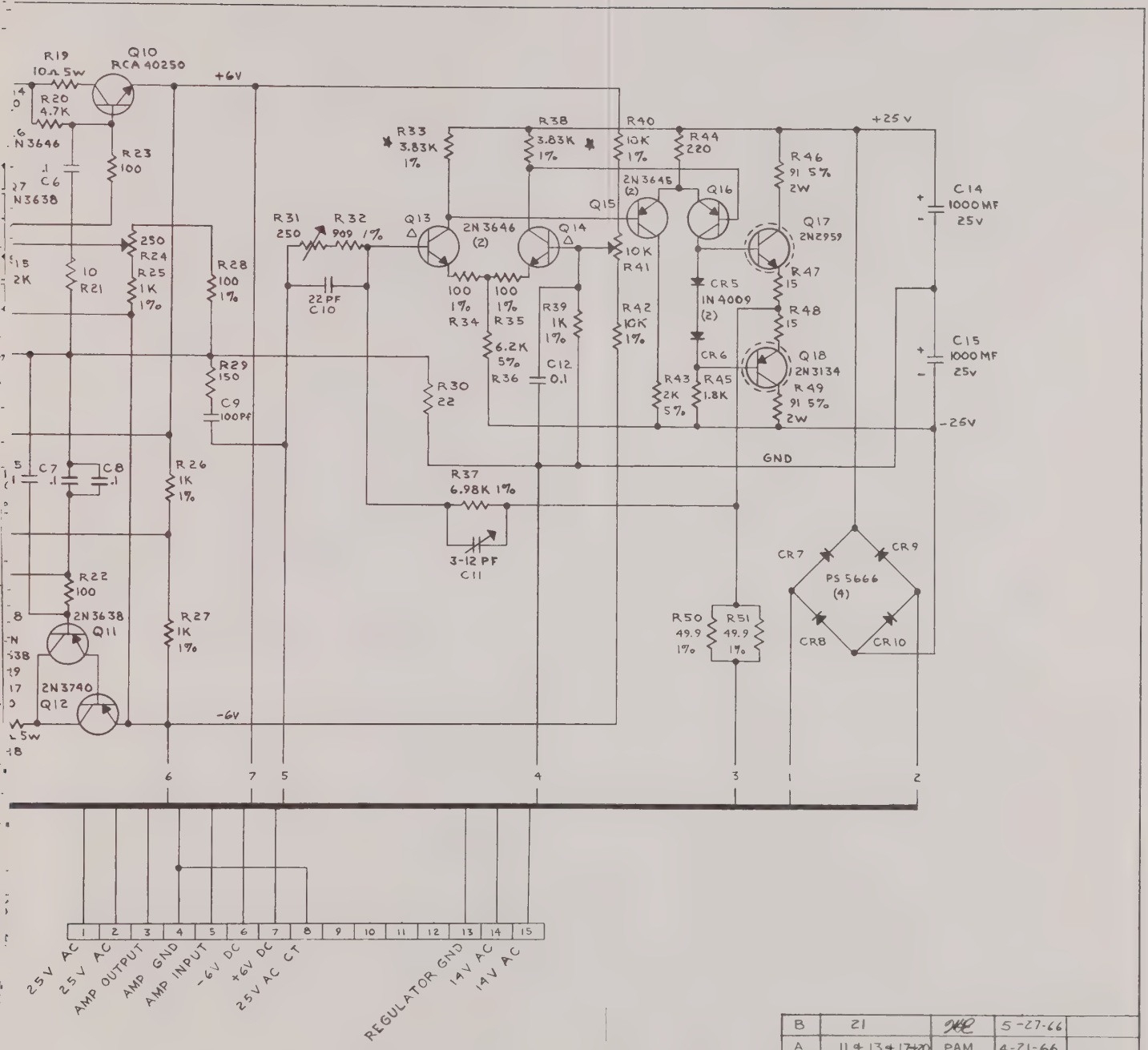
✱ INDICATES MATCHED PAIR

HEAT SINKS

NOTE

UNLESS OTHERWISE SPECIFIED :

1. RESISTANCE IN OHMS, ±10%
2. CAPACITANCE IN MICROFARADS, ±10%
3. DIODES ARE 1N4009
4. PINS ARE NUMBERED FROM LEFT TO RIGHT AS VIEWED FROM COMPONENT SIDE OF CIRCUIT BOARD
5. ALL DIFFERENTIAL PAIRS MATCHED FOR 10% β MATCH
6. △ INDICATES THERMALLY CONNECTED



PAIRS

B	21	~~JHR~~	5-27-66	
A	11 & 13 & 17 & 20	PAM	4-21-66	
CHG	ECN NO.	BY	DATE	APP

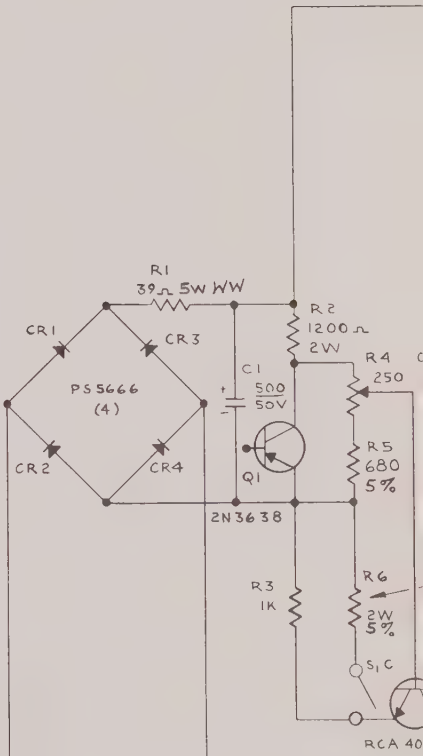
WAVETEK 8159 ENGINEER RD SAN DIEGO, CALIF.

DRN PA Marsh DATE 1-21-66 APP Jerry Foster

POWER SUPPLY AND OUTPUT AMP

MODEL 110, 111, 112, 115 NO 110-204B

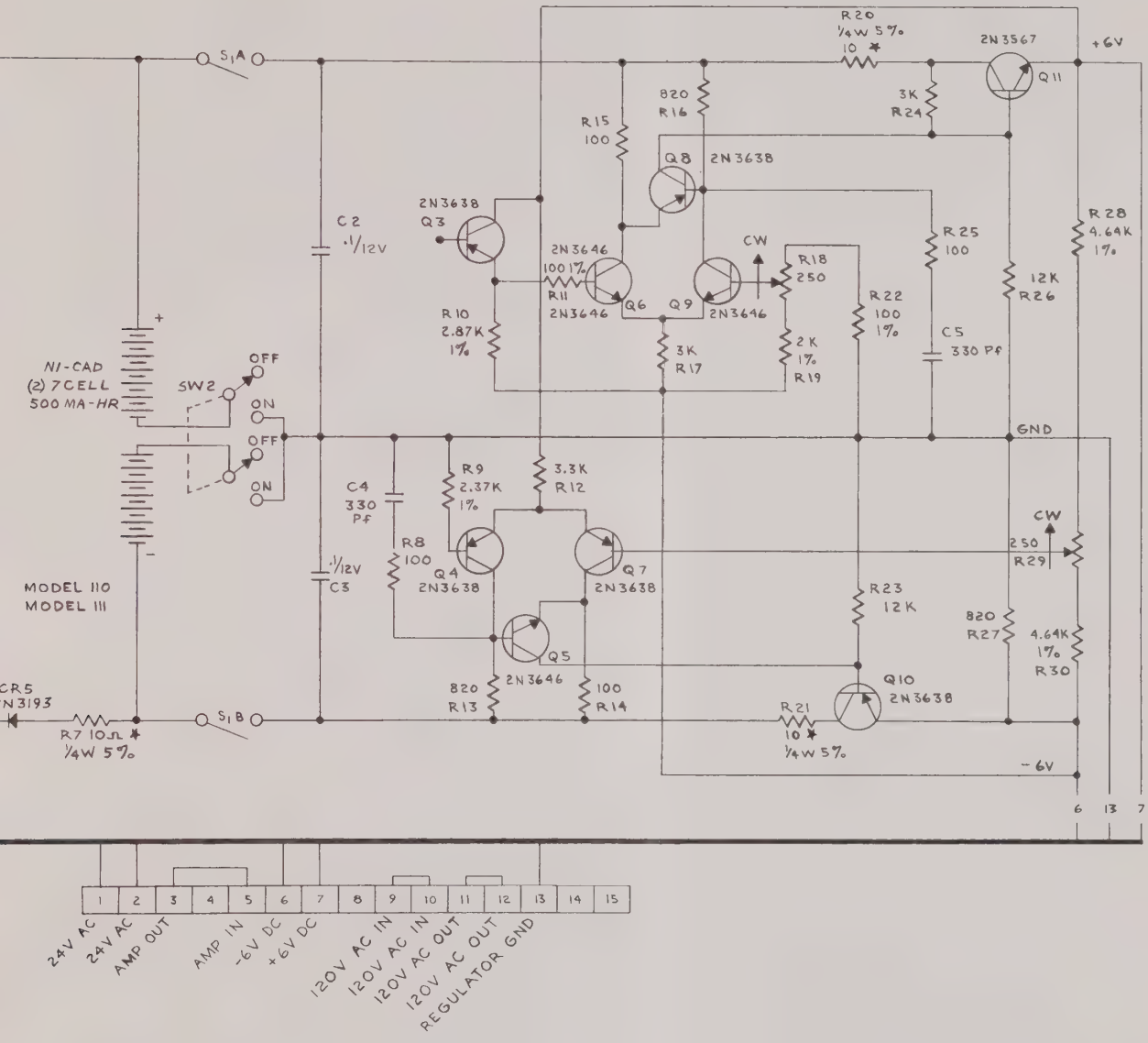
Power Supply and Output Amplifier Schematic Diagram



NOTE

UNLESS OTHERWISE SPECIFIED:

1. RESISTANCE IN OHMS
2. CAPACITANCE IN MICROFARADS
3. PINS ARE NUMBERED FROM LEFT TO RIGHT AS VIEWED FROM COMPONENT SIDE OF CIRCUIT BOARD
4. * MOUNT 1/4 INCH OFF BOARD (FUSE RESISTORS)
5. LABLED PINS ONLY, ACTUALLY APPEAR ON CIRCUIT BOARD



B	28	JW	7-13-6	
A	15	RLM	4-22-66	
CHG	ECN NO.	BY	DATE	APP

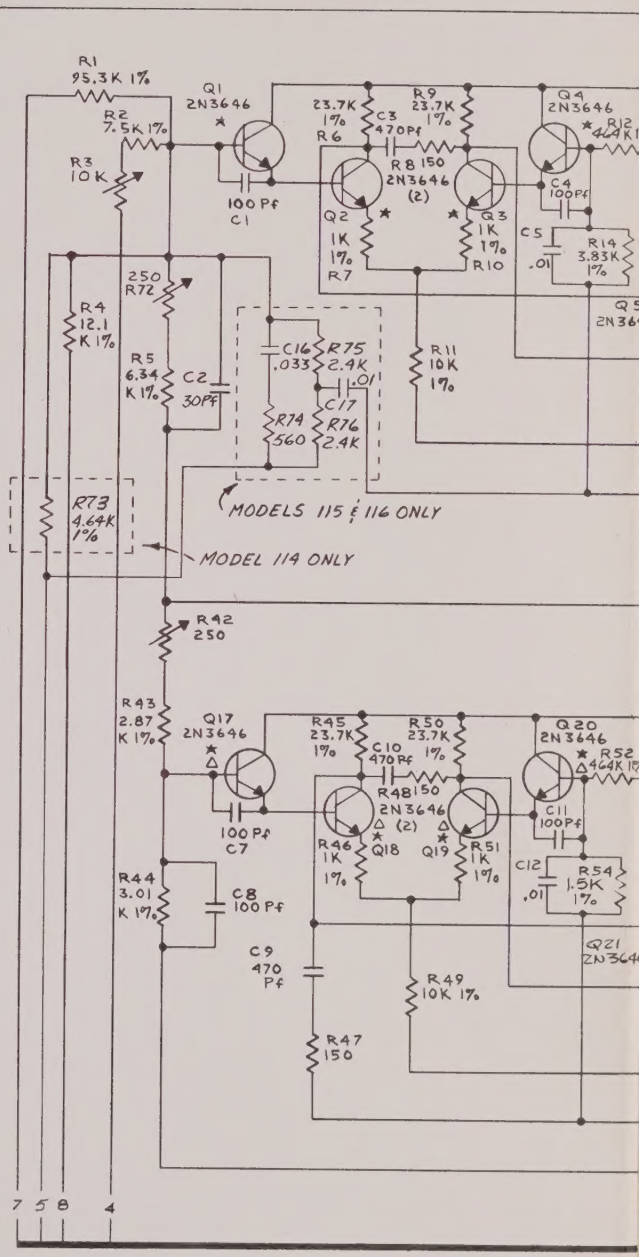
WAVETEK 8159 ENGINEER RD SAN DIEGO, CALIF

DRN PA Marsh DATE 1-27-66 APP Arthur J. Fan

BATTERY POWER SUPPLY

MODEL 110B-111B NO 110B-204B

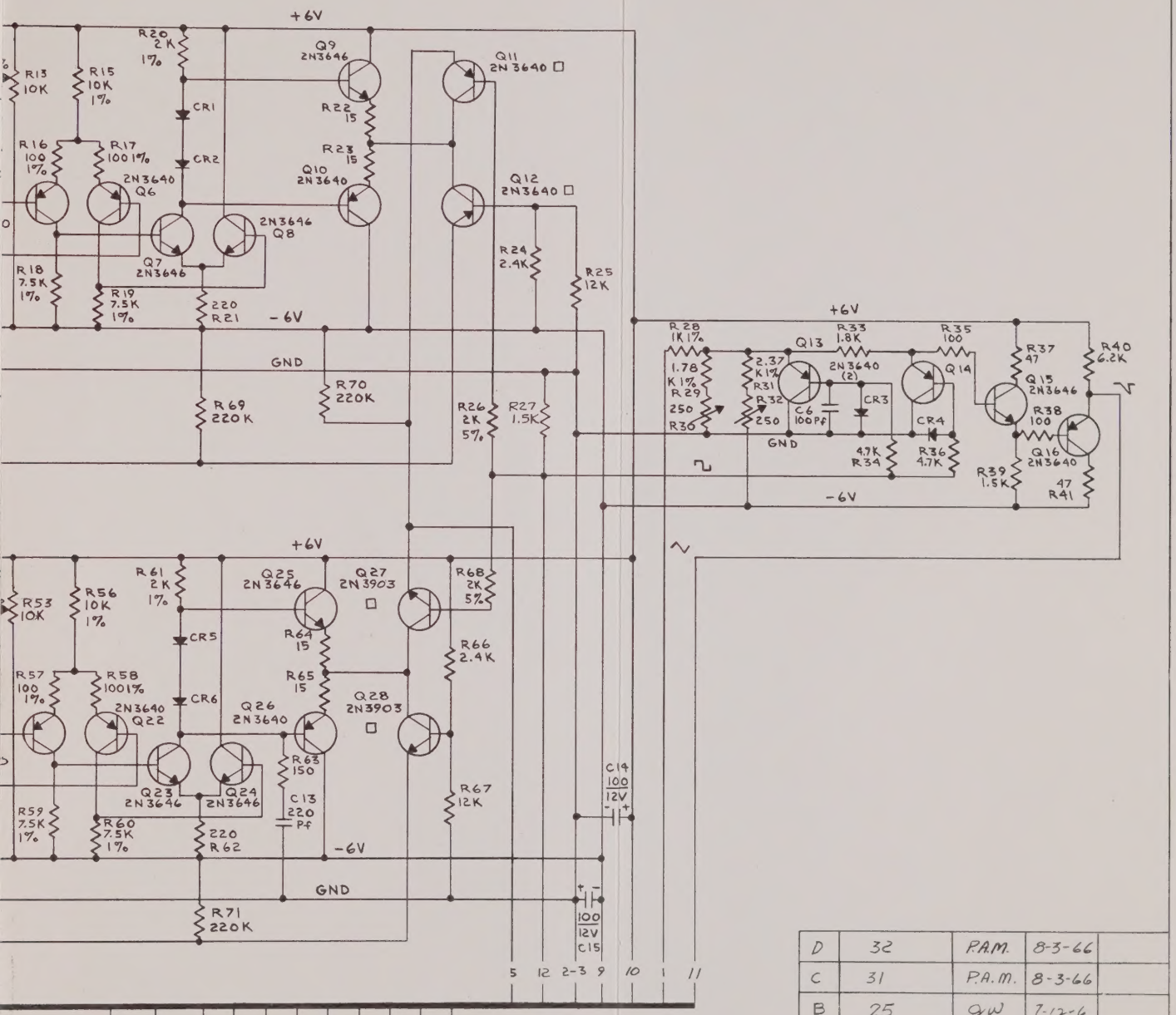
Battery Power Supply Schematic Diagram



NOTE

UNLESS OTHERWISE SPECIFIED :

1. RESISTANCE IN OHMS
2. CAPACITANCE IN MICROFARADS
3. ALL DIODES 1N4009
4. PINS ARE NUMBERED FROM LEFT TO RIGHT AS VIEWED FROM THE COMPONENT SIDE OF CIRCUIT BOARD
5. □ MATCHED PAIR, V_{CE} SAT.
6. ✱ MATCHED PAIR – MATCHED FOR β AND V_{BE}
7. ALL DIFFERENTIAL PAIRS MATCHED FOR 10% β MATCH
8. Δ INDICATES THERMALLY CONNECTED PAIRS
9. PIN #5 NOT USE IN MODE



D	32	P.A.M.	8-3-66	
C	31	P.A.M.	8-3-66	
B	25	gw	7-12-6	
A	11	P.A.M.	4-22-66	
CHG	ECN NO.	BY	DATE	APP

WAVETEK 8159 ENGINEER RD SAN DIEGO, CALIF

DRN PA March DATE 1-25-66 APP Jerry Foote

VCG BOARD

MODEL 111,111B,112,115 NO 111-203C

VCG Board Schematic Diagram